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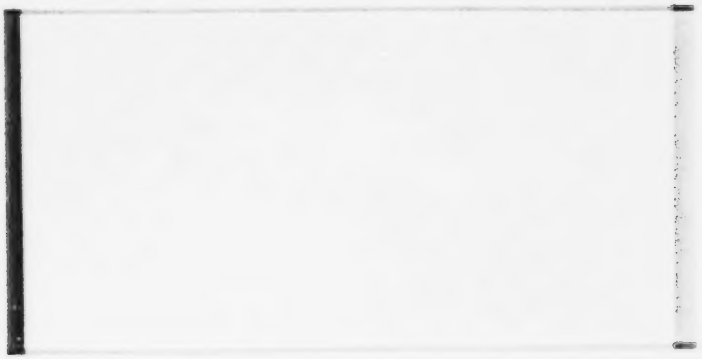

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BRUCE NGS-A PRESSURE TUBE ELONGATION STUDY

Report No 86-67-K

R.G. Fishell
Engineer
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ABSTRACT

The fast neutron flux profiles for the Bruce NGS-A pressure tubes were updated using the same methods as were used for the Pickering NGS-A unit 3 and 4 pressure tubes. The correlation between pressure tube elongation and fast neutron fluence was examined. A SAS program was created to calculate the elongation rates for individual pressure tubes based on successive measurements for each pressure tube over time. The current elongation rate was found to be in the neighbourhood of 0.099 to 0.110 mm/GWH. Little evidence was found of an acceleration factor in the pressure tube elongation rates.

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TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	THE STUDY	2
3.	RESULTS	2
	3.1 Bulk Elongation Rates	2
	3.2 Channel Elongation Rates	2
	3.3 Analysis	2
4.	CONCLUSIONS AND REMARKS	3
	REFERENCES	4
	FIGURES	5
	1-12 BULK ELONGATIONS PLOTS	6 - 17
	13-16 BULK ELONGATIONS (OVERLAYS BY UNIT)	18 - 21
	17-20 BULK ELONGATIONS (AVERAGED TO 10 GWH BANDWIDTHS)	22 - 25
	21-33 CHANNEL ELONGATION PLOTS	26 - 38
	34-38 CHANNEL ELONGATIONS (OVERLAYS BY UNIT)	39 - 43
	39-42 CHANNEL ELONGATIONS (AVERAGED TO 10 GWH BANDWIDTHS)	44 - 47
	APPENDICES	48
	I BULK ELONGATION RATES	49
	II CHANNEL ELONGATION RATES	50
	III SELECTED CHANNEL ELONGATION RATE DATA	51

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research division

To Mr. B. Montford
Manager - Chemistry and Metallurgy
Central Nuclear Services
Technical & Training Services Division

BRUCE NGS-A PRESSURE TUBE ELONGATION STUDY

R.G. Fishell

1. INTRODUCTION

The study was commissioned by the Fuel Channel Materials Section of the Chemistry and Metallurgy Department of Central Nuclear Services. The objective of this study was to update elongation measurements and fast neutron fluences for the Bruce-A nuclear reactor units. The study included a statistical analysis to calculate systematically the elongation rates and to identify any major trends with the appropriate plots.

The study provides a comprehensive study of Bruce elongation measurements similar to the earlier study of Pickering NGS-A units 3 and 4 by D.C. Goushleff/1/. All Bruce-A elongation (both the complete and the selected measurement sets) measurements were included in the analysis.

The analysis focused on the effect of fast neutron fluence on pressure tube elongation. For consistency, fast neutron fluence has been converted to GWHs.

2. THE STUDY

The first part of the study consisted of updating the Fast Neutron Fluence data files for all the Bruce NGS-A reactors which are maintained by the Fuel Channel Materials Section. These are based on the SORO flux maps generated by the Fuel and Physics Department.

The second part of the study consisted of establishing a SAS(*) data base for the Bruce-A elongation data and the respective fluences. A SAS program was set up which plotted and analyzed an elongation rate (elongation vs. GWH) for a given set of measurement taken during an outage. This calculated rate is referred to as the **Bulk Elongation Rate.**

* SAS (Statistical Analysis System) is a commercially available statistical analysis computer package operating on Hydro's IBM mainframe computer/4, 5/.

8667

The SAS program also analyzed the elongation rates referred to as **Channel Elongation Rates** derived from successive measurements of the same channel. These **Channel Elongation Rates** were then regressed to check for an acceleration factor in the elongation trends. The SAS program also includes plots of these Channel Elongation Rates.

To help identify major trends, the analyses were repeated after grouping the data into convenient 10 GWH bandwidths and then averaging the data points and plotting the resulting data.

3. RESULTS

3.1 Bulk Elongation Rates

The bulk elongation rates represent the total elongation of pressure tubes at a given point in time correlated against the total fast neutron fluence in GWH. The bulk elongation rates are presented in Appendix I by unit and by measurement set. These rates were found to be highly consistent with each other and are in accordance with the rates identified previously for PNGS-A units 3 and 4/1, 2, 3/.

Figures 1-12 represent the plots of the Bulk Elongation rates of the four Bruce NGS-A reactors. Included in the plots are all the complete measurement sets of all the channels for each of the Bruce NGS-A units plus some additional measurement sets of selected channels.

Figures 13-16 overlay successive measurements of the same unit on a single plot. In Figures 13 and 14, the full sets of measurements have similar slopes indicating a constant elongation rate. The selected measurement sets (Unit 1-1978 and Unit 2-1985#1) have different slopes mostly due to the small sample size and the small range in the GWHs in the data points. Figure 15 shows evidence of a systematic shift in elongation measurements in one of the data sets as witnessed by similar but offset slopes.

In Figures 17-20 the data have been grouped into 10 GWH bandwidths for added clarity. The overlapping of the data points and the linear shape of the curves (especially in figures 17 & 18) further support the evidence that the elongation is linear and relatively constant.

3.2 Channel Elongation Rates

The Channel Elongation Rates represent the ratio of the change in a channel's elongation and the change in the channel's fast neutron fluence (shown in GHWs) over a given period, correlated against the average channel GWH over the same period. Figures 21-33 represent the Channel Elongation Plots by Unit and by Period.

The channels which were measured when a complete set of elongation measurements were taken are labelled as **Mask=1** on the plots (See Appendix II). The rates determined when comparing full measurement sets show a very gentle positive slope (Figures 21, 25-27, 32, and 33). This can be interpreted as a small acceleration in the elongation rate over time. To date there has not

been a significant increase in the rates.

The channels that have supplementary measurements taken are labelled as **Mask=2** on the plots. The rates from the supplementary measurement sets do not have a large enough sample size to yield consistent results. These slopes (seen in Figures 22-24 and 28-31) show no consistent trend or magnitude. Figures 34-38 show the same plots by Unit with the successive measurement periods overlayed on the same plot.

In Figures 39-42 all the points have been grouped into 10 GWH bandwidths. This averaging gives a better indication of trends but hides the variance.

3.3 Analysis

Examination of both the Bulk Elongation Rates (Appendix I) and the Channel Elongation Rates (Appendices II and III) indicates that the elongation rates remain almost constant. The rates determined from the Bulk Elongation Rates look constant within the margin of error. The rate of acceleration determined from the Channel Elongation Rates is very small and apparently constant.

The Channel Elongation Rates from the supplementary data (Appendix II where Mask=2) show differing results to each other and to the complete data sets. This is due to a small sample size which makes the data very sensitive to any small systematic measurement errors. This is most obvious when the two sets of 1985 measurements for Unit 2 are compared. If taken alone, there seems to be a significant increase in the elongation rate during the period defined by the two 1985 measurement sets. However, the elongation rates of the channels appears to be smaller in the 1982-1985 (1st set) period and quite normal if the second 1985 set is compared to the 1982 data. This implies a slight systematic measurement error in the first 1985 data set rather than a change in the elongation rate during 1985 (see Appendix III).

4. CONCLUSIONS AND REMARKS

There is no indication of significant change in the rate of elongation of the pressure tubes in the Bruce NGS-A reactors over the eight years of their operation.

The selected measurement sets that examine only a small sample size do not yield much information about the overall elongation trends and should not be used as an alternative to complete measurement sets. These sets are, however, useful in tracking the longest or critical channels. When investigating overall elongation rates and trends, only complete measurement sets should be analyzed.

The **Bulk Elongation Rates** and Plots are the simplest and most common method of examining the elongation trends. However, it should be remembered that they compare the total elongation against the total GWH from start-up to the measurement date; they are NOT a snapshot of current trends. The **Channel Elongation Rates** will, however, give information as to trends between a specified measurement period. Indications of acceleration, if present, can be

determined by examining the change in **Channel Elongation Rates** against increasing fluence (or GWH) as was done in Figures 21-33.

Approved:

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Submitted:

R G. Fishell

R.G. Fishell
Engineer
Operations Research Section

RGF:cmh

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1. Goushleff, D.C., "Pressure Tube Elongation Rate Study for PNGS-A Units 3 and 4". Ontario Hydro Research Division. Report No 84-289-K, October 31, 1984.

2. Chung, A.H., and Punhani, A.L., "Correlation of Pressure Tube Elongation with Fast Neutron Fluence and Operating Temperature in Pickering NGS-A, Units 3 and 4". Ontario Hydro Research Division. Report No 78-412-k, October 12, 1978.

3. Causey, A.R., "P3 and P4 Pressure Tube Elongation Rates". AECL Memorandum to Norsworthy, A.G., February 10, 1984.

4. "SAS User's Guide: Basics, Version 5 Edition." SAS Institute Inc. POB 8000 Cary, North Carolina, 1985.

5. "SAS/GRAPH User's Guide: Version 5 Edition." SAS Institute Inc. POB 8000 Cary, North Carolina, 1985.

FIGURES

FIGURE 1

BRUCE-A ELONGATION DATA
REGRESSION ANALYSIS
UNIT=1 YEAR=1978

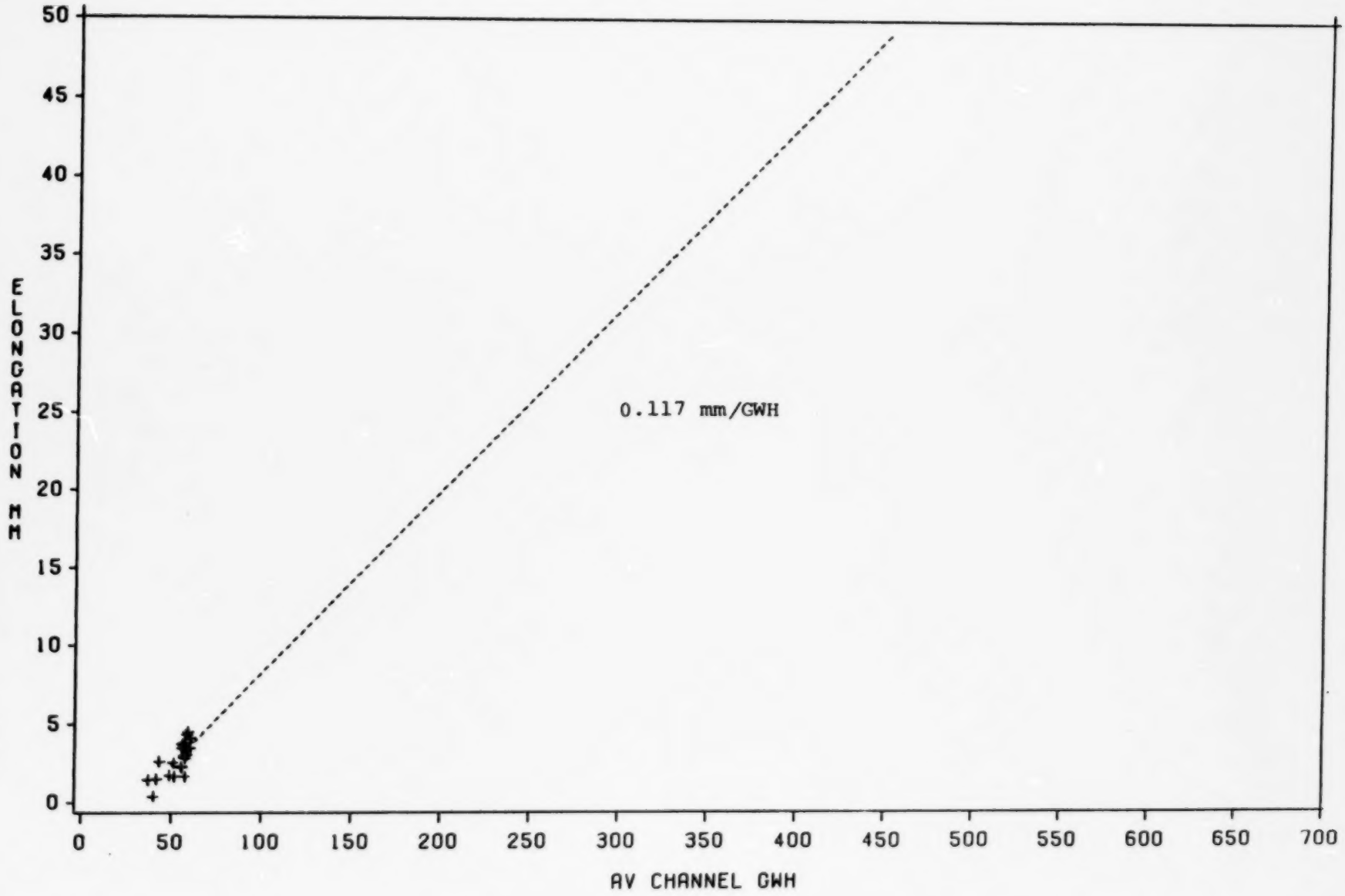

FIGURE 2

BRUCE-A ELONGATION DATA
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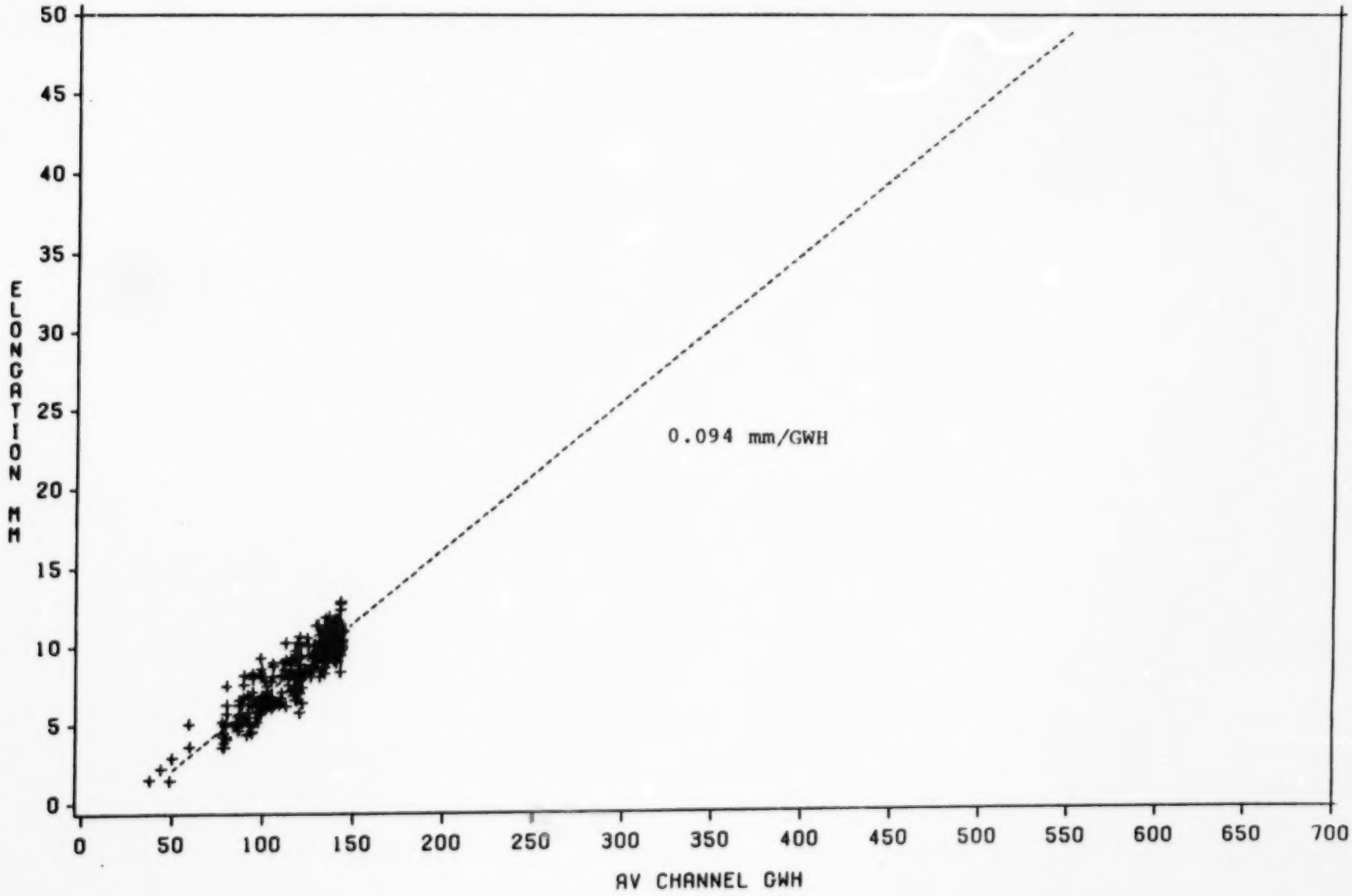

FIGURE 3
BRUCE-A ELONGATION DATA
REGRESSION ANALYSIS
UNIT=1 YEAR=1983

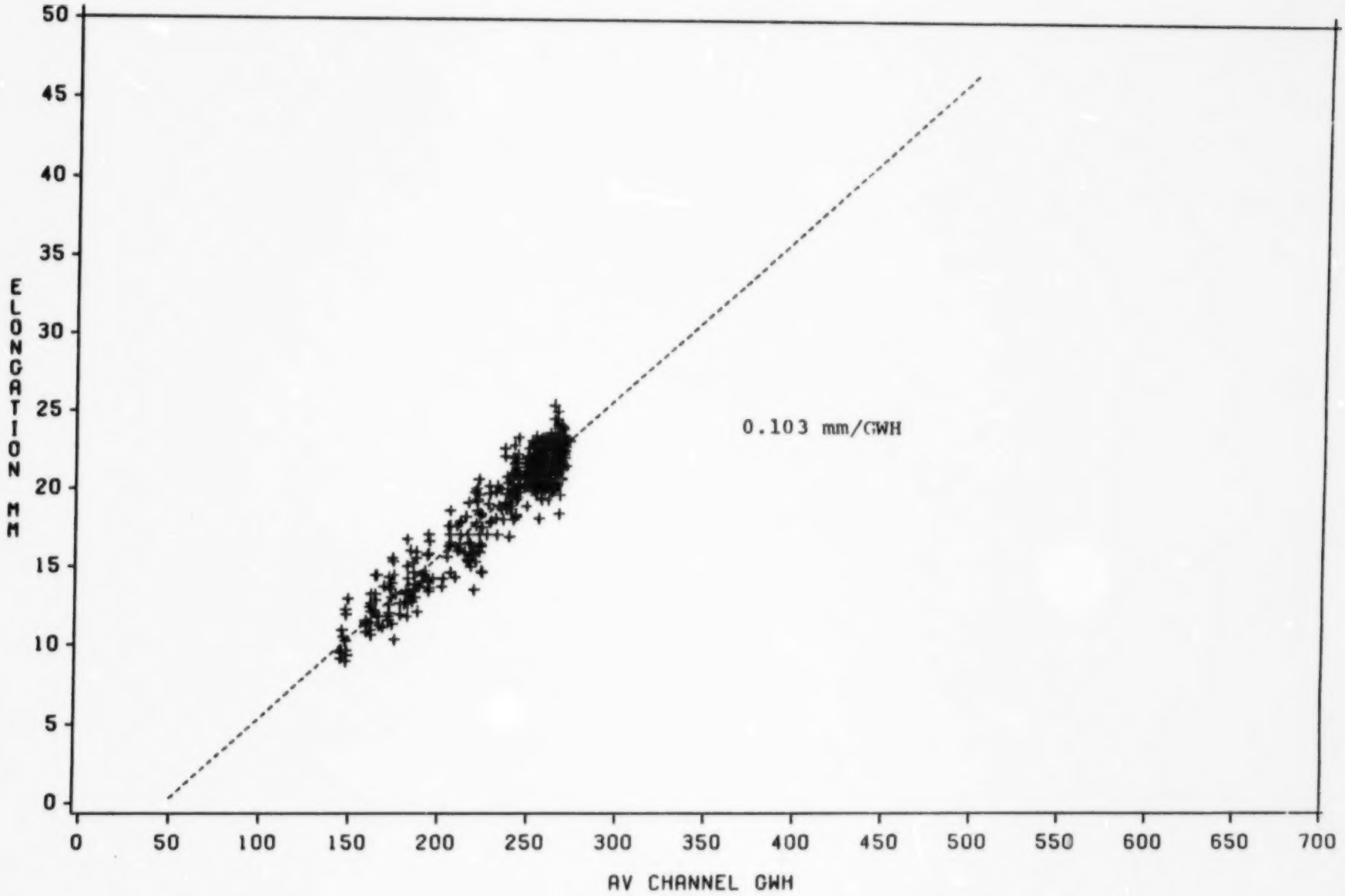

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FIGURE 4

BRUCE-A ELONGATION DATA
REGRESSION ANALYSIS
UNIT=2 YEAR=1979

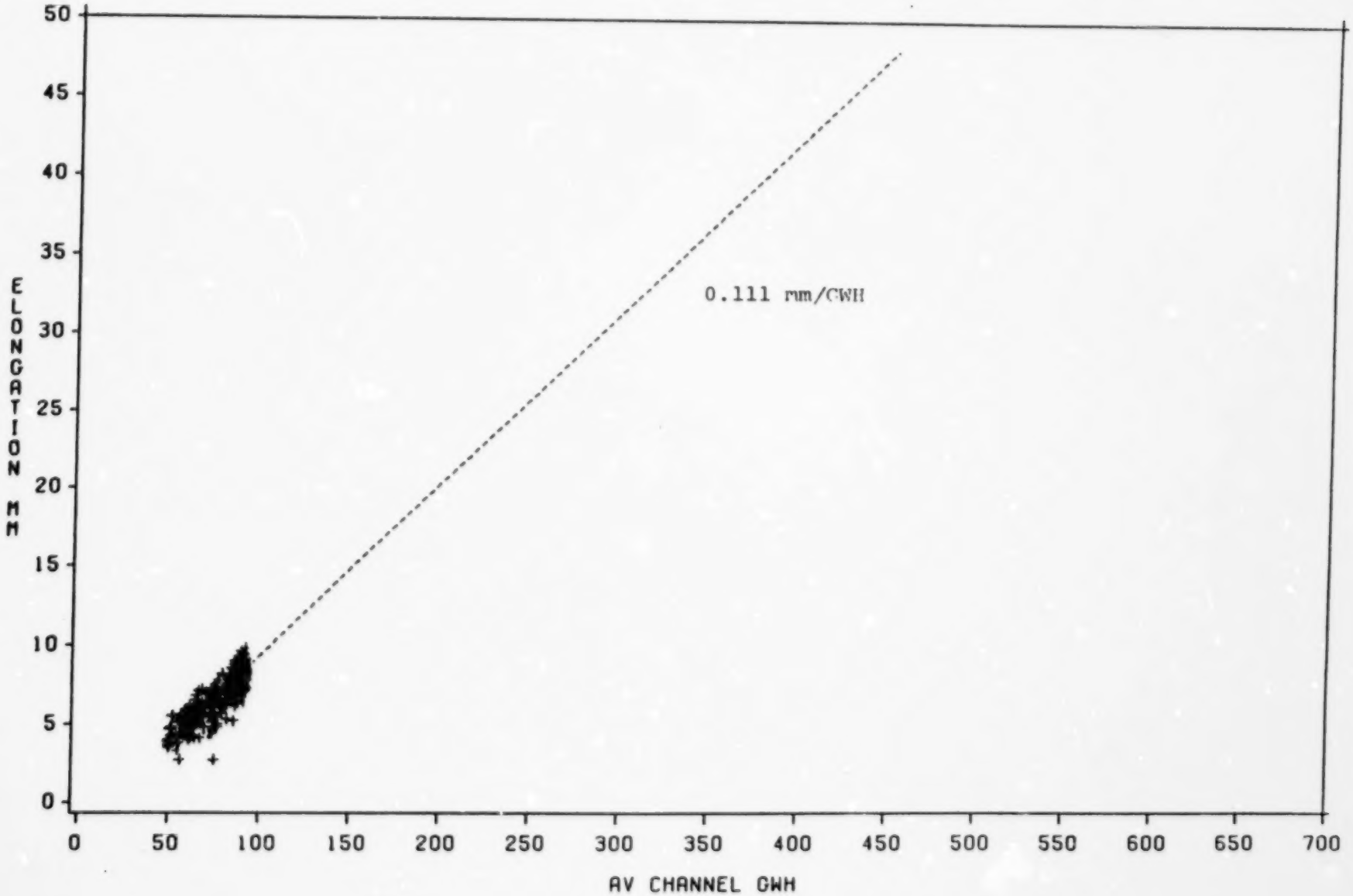

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FIGURE 5

BRUCE-A ELONGATION DATA
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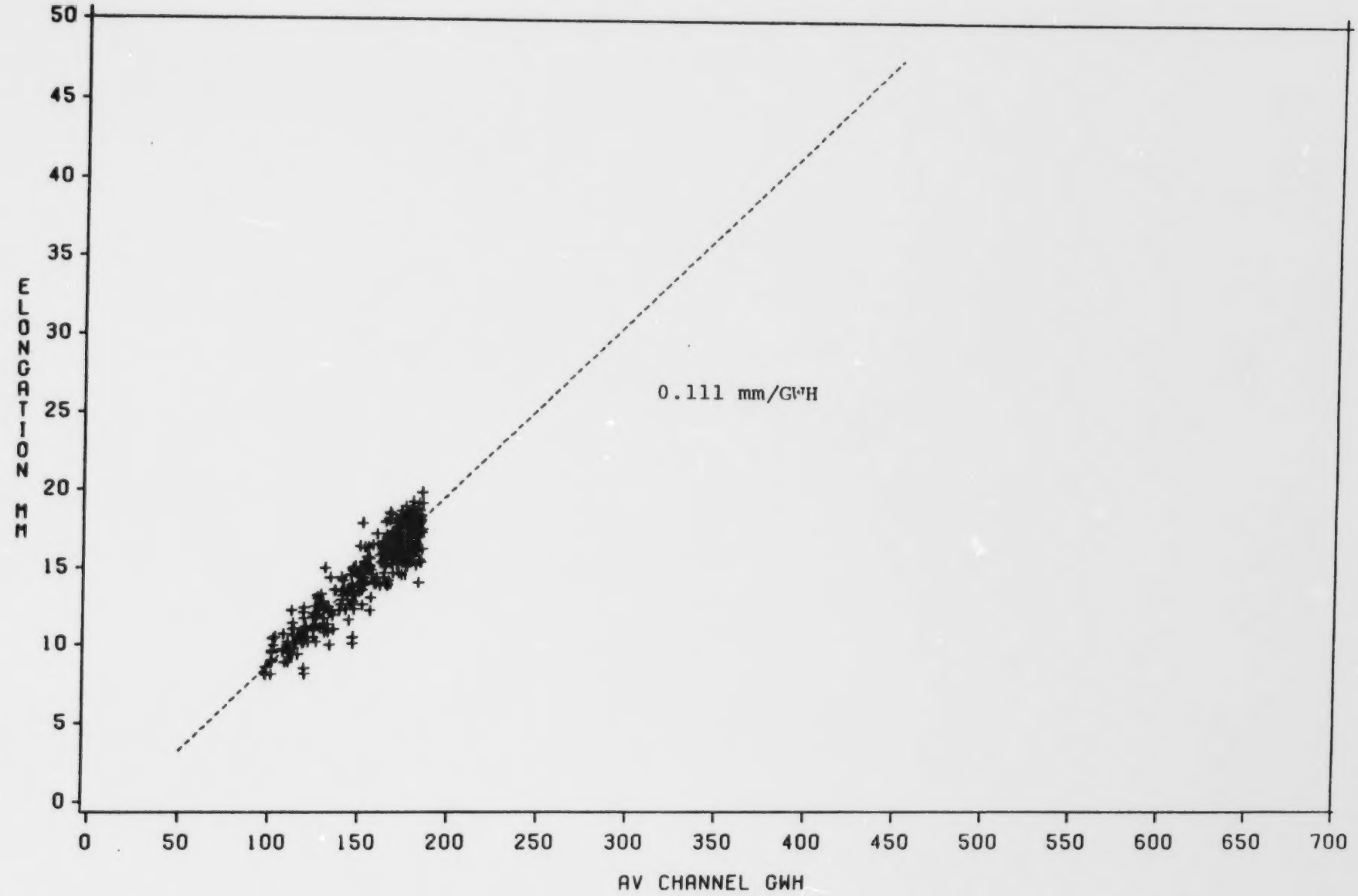
UNIT=2 YEAR=1981



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BRUCE-A ELONGATION DATA
REGRESSION ANALYSIS
UNIT=2 YEAR=1982

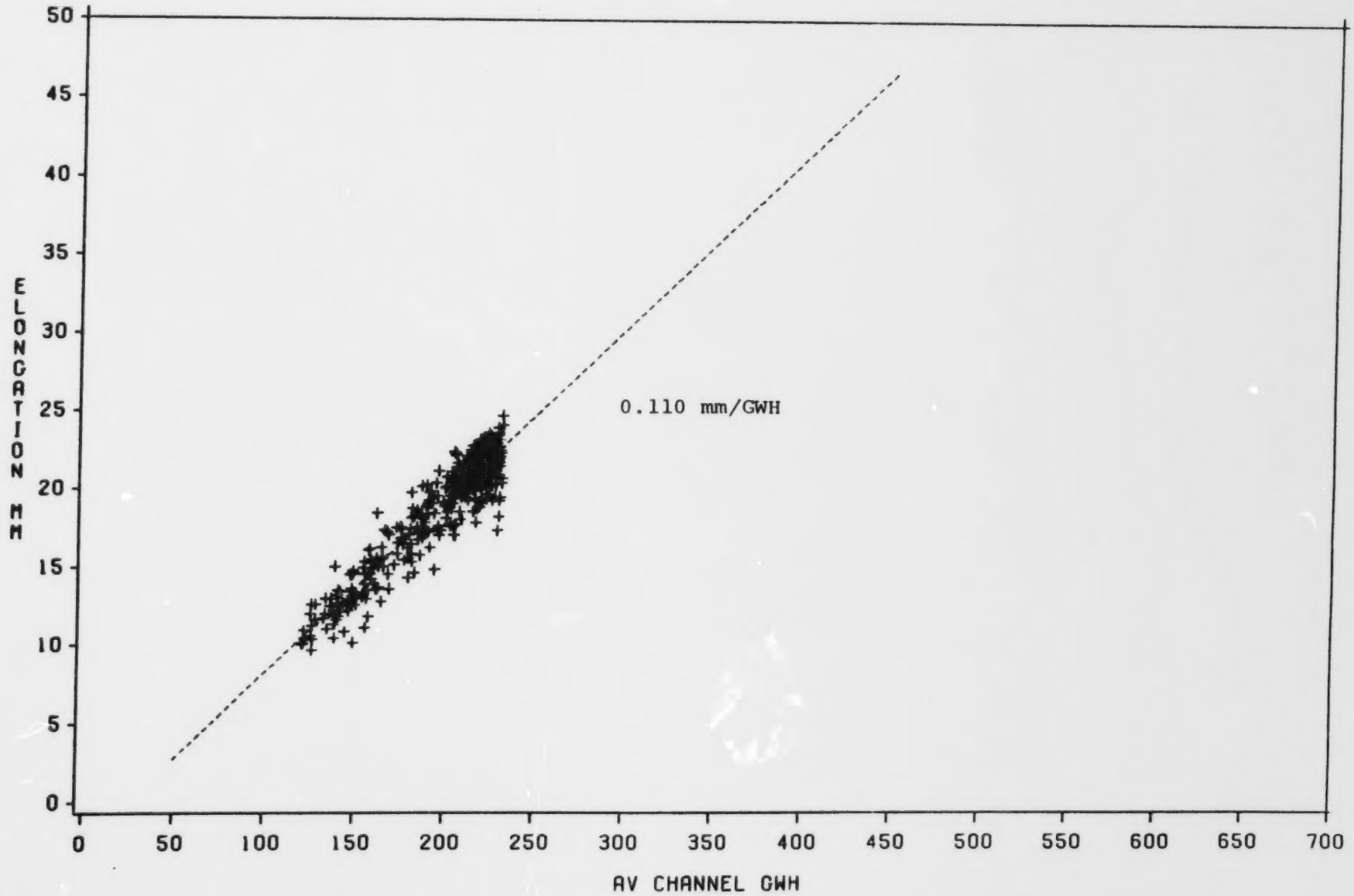

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FIGURE 7

BRUCE-A ELONGATION DATA
REGRESSION ANALYSIS
UNIT=2 YEAR=1985 #1

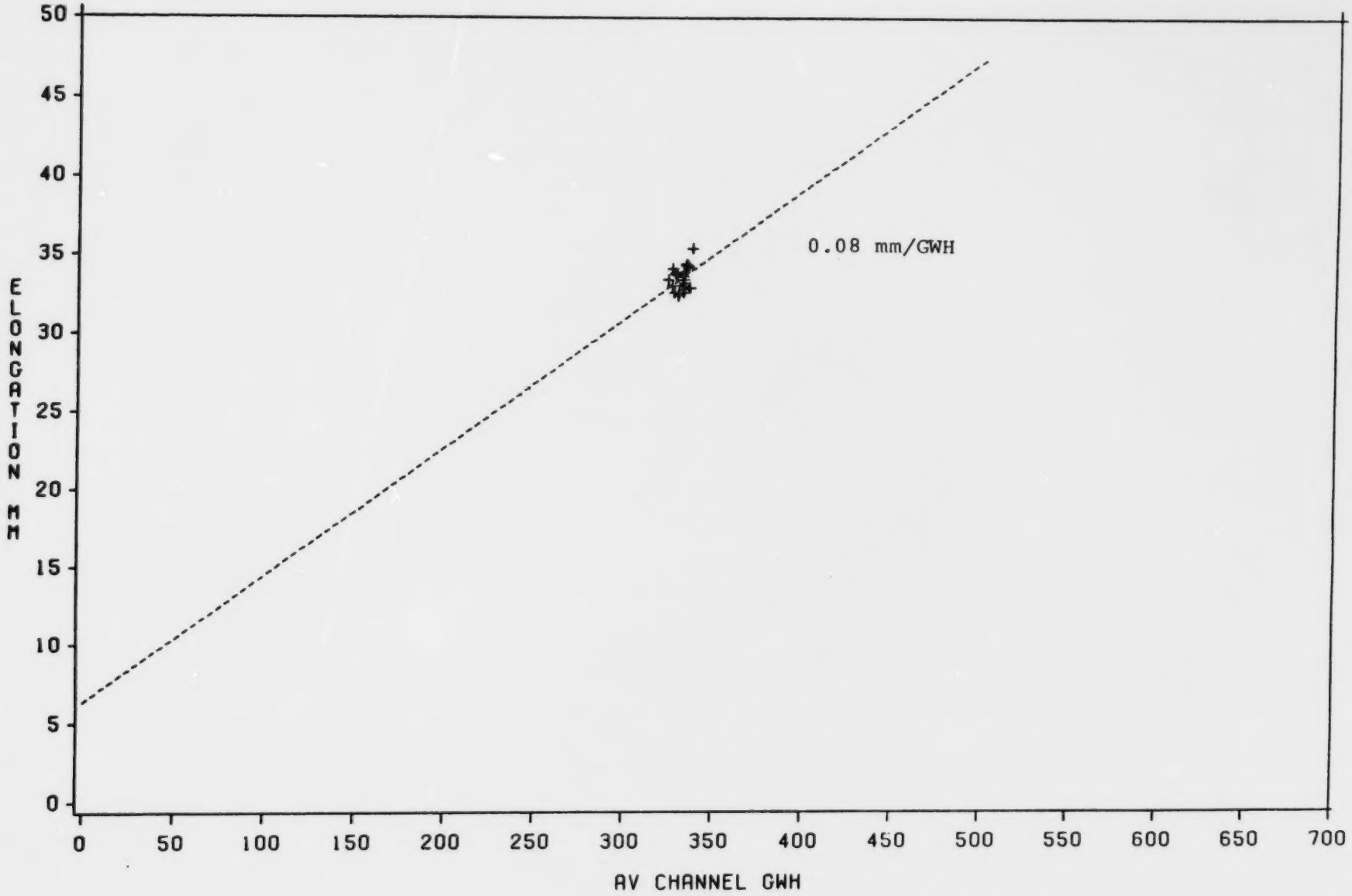
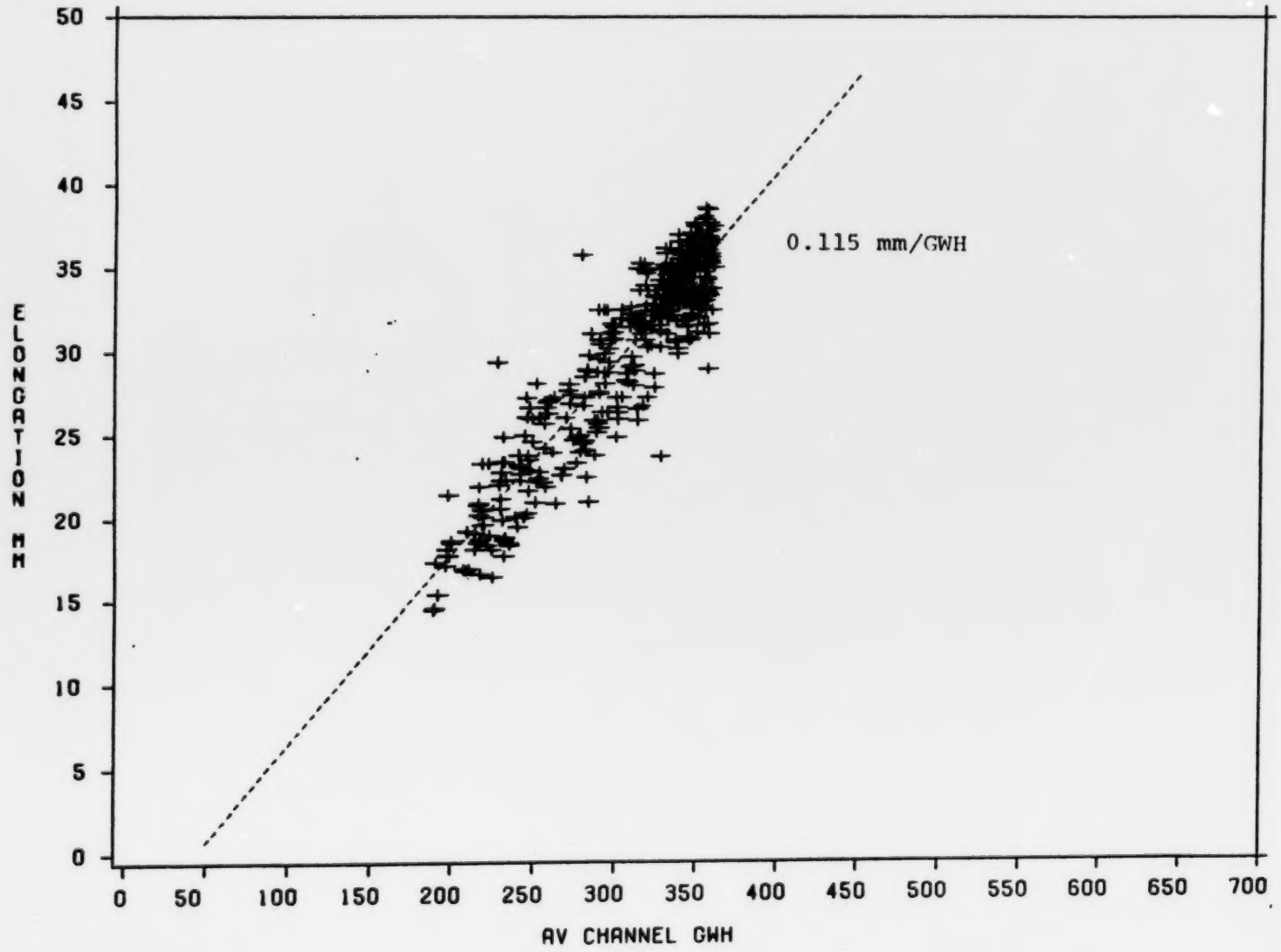


FIGURE 8
BRUCE - A ELONGATION DATA
Regression Analysis
Unit=2 Year=1985 #2



FIGURE

BRUCE-A ELONGATION DATA
REGRESSION ANALYSIS
UNIT=3 YEAR=1981

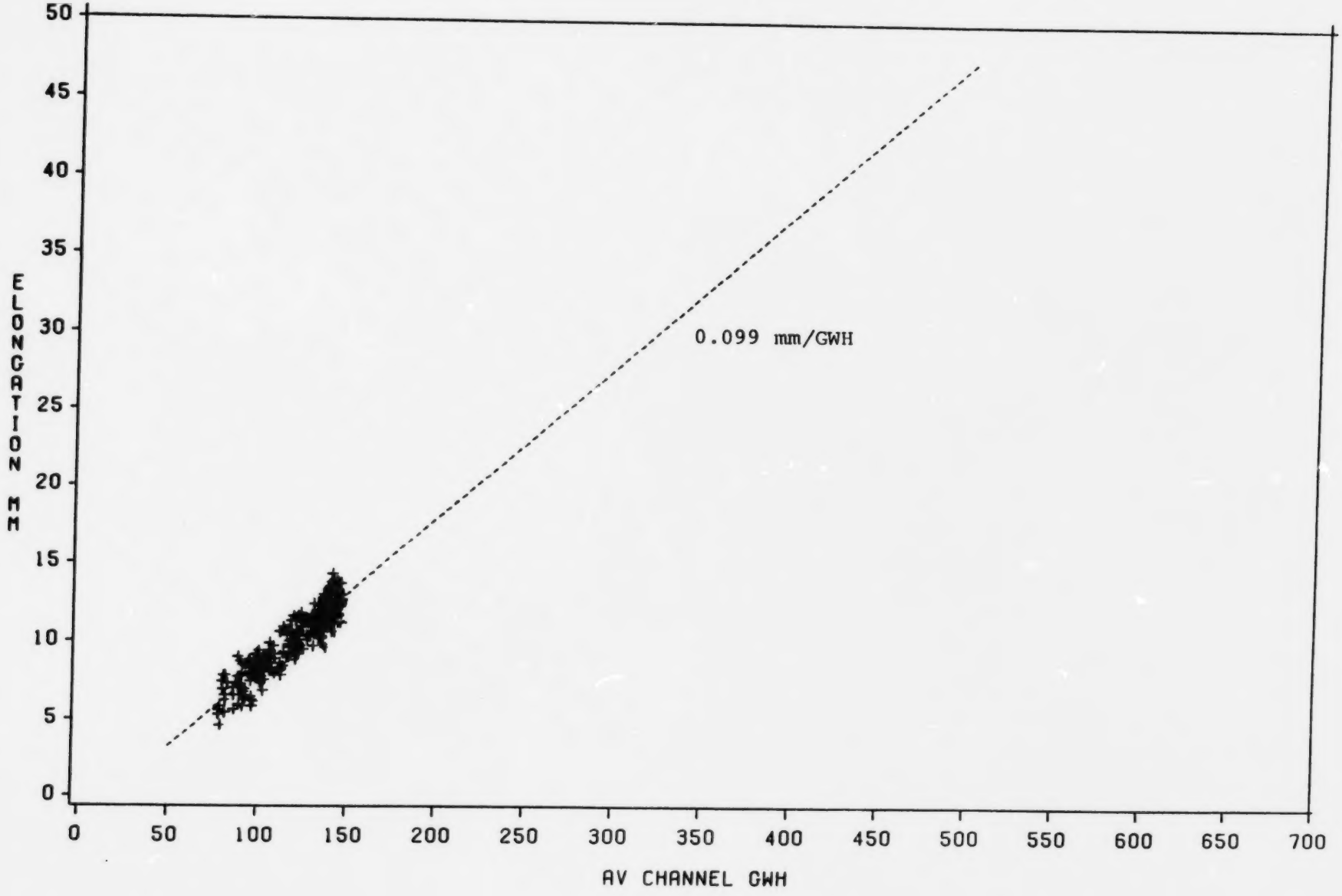


FIGURE 10

BRUCE-A ELONGATION DATA
REGRESSION ANALYSIS
UNIT=3 YEAR=1983

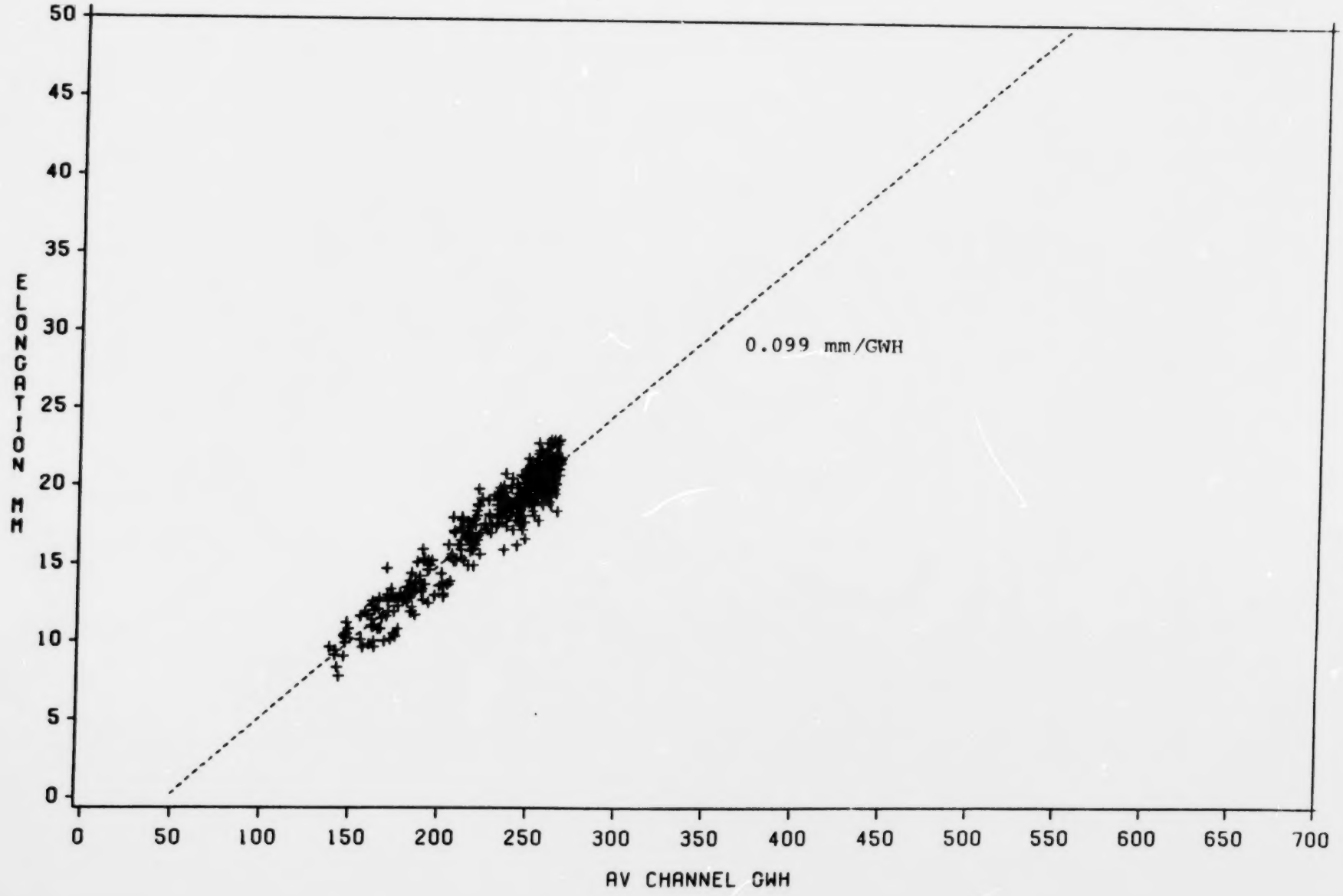


FIGURE 11

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UNIT=4 YEAR=1980

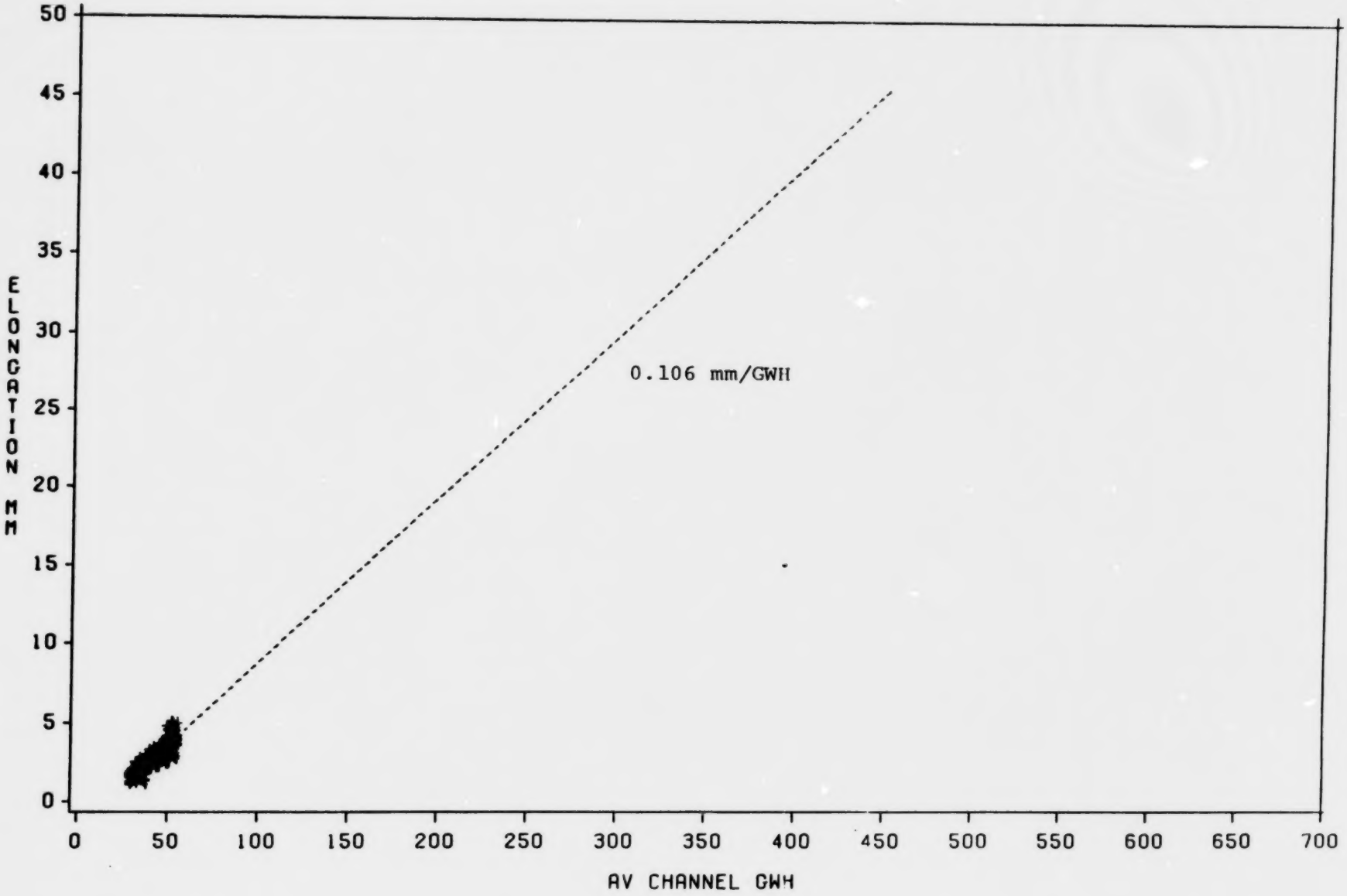

FIGURE 12

BRUCE-A ELONGATION DATA
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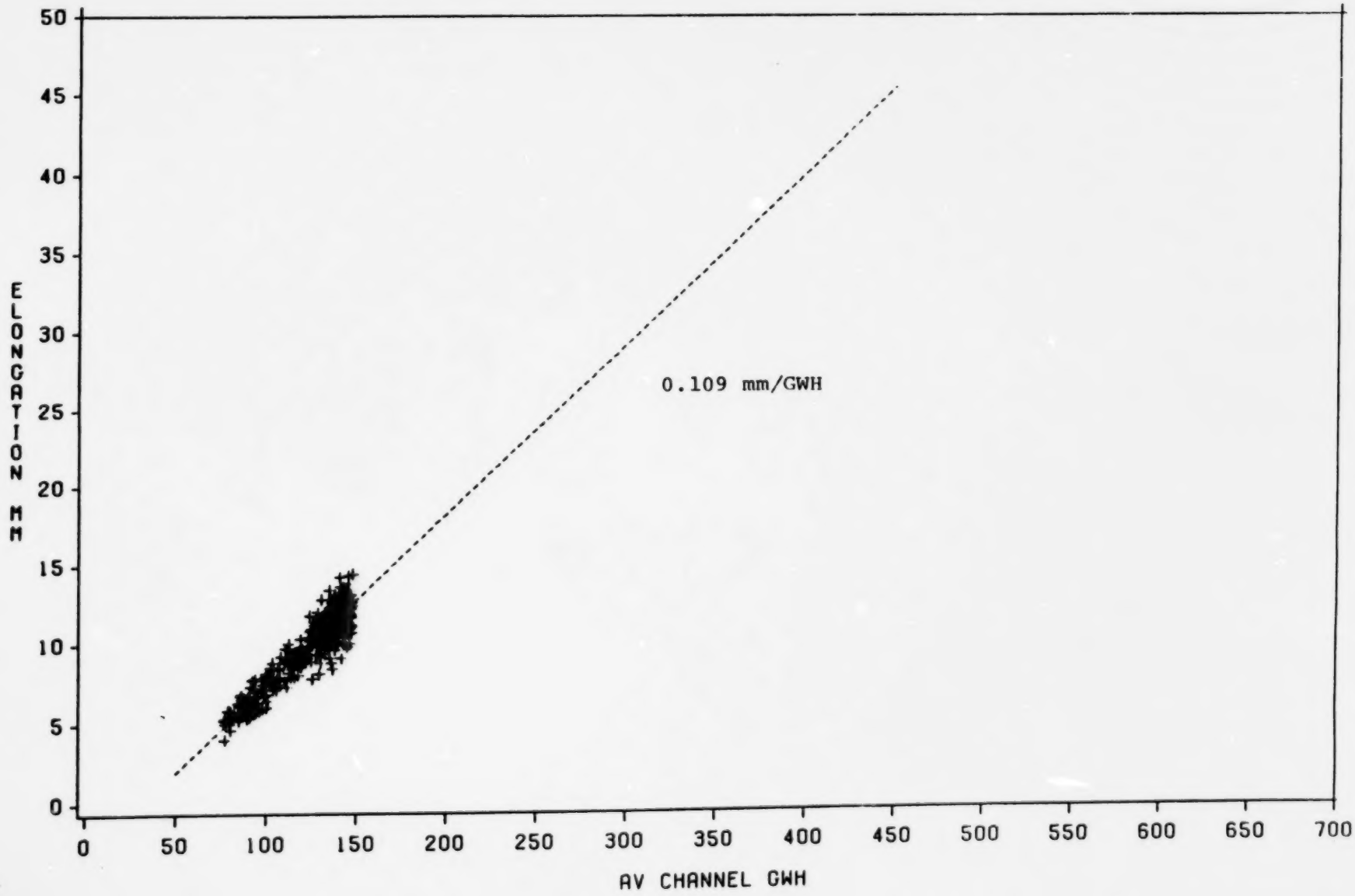

FIGURE 15

BRUCE-A ELONGATION DATA
BULK DATA
UNIT=1

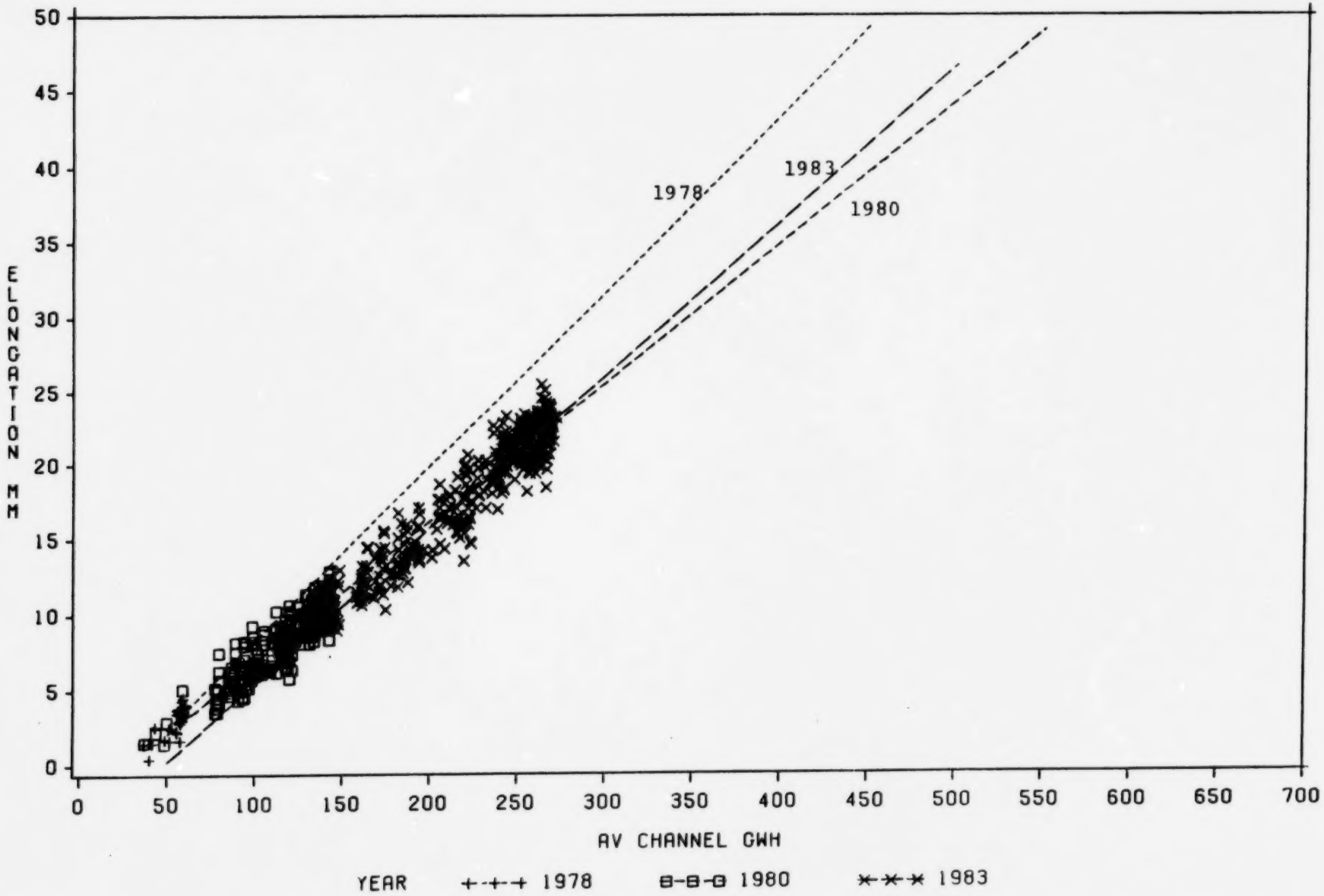

FIGURE 14
BRUCE - A ELONGATION DATA
BULK DATA
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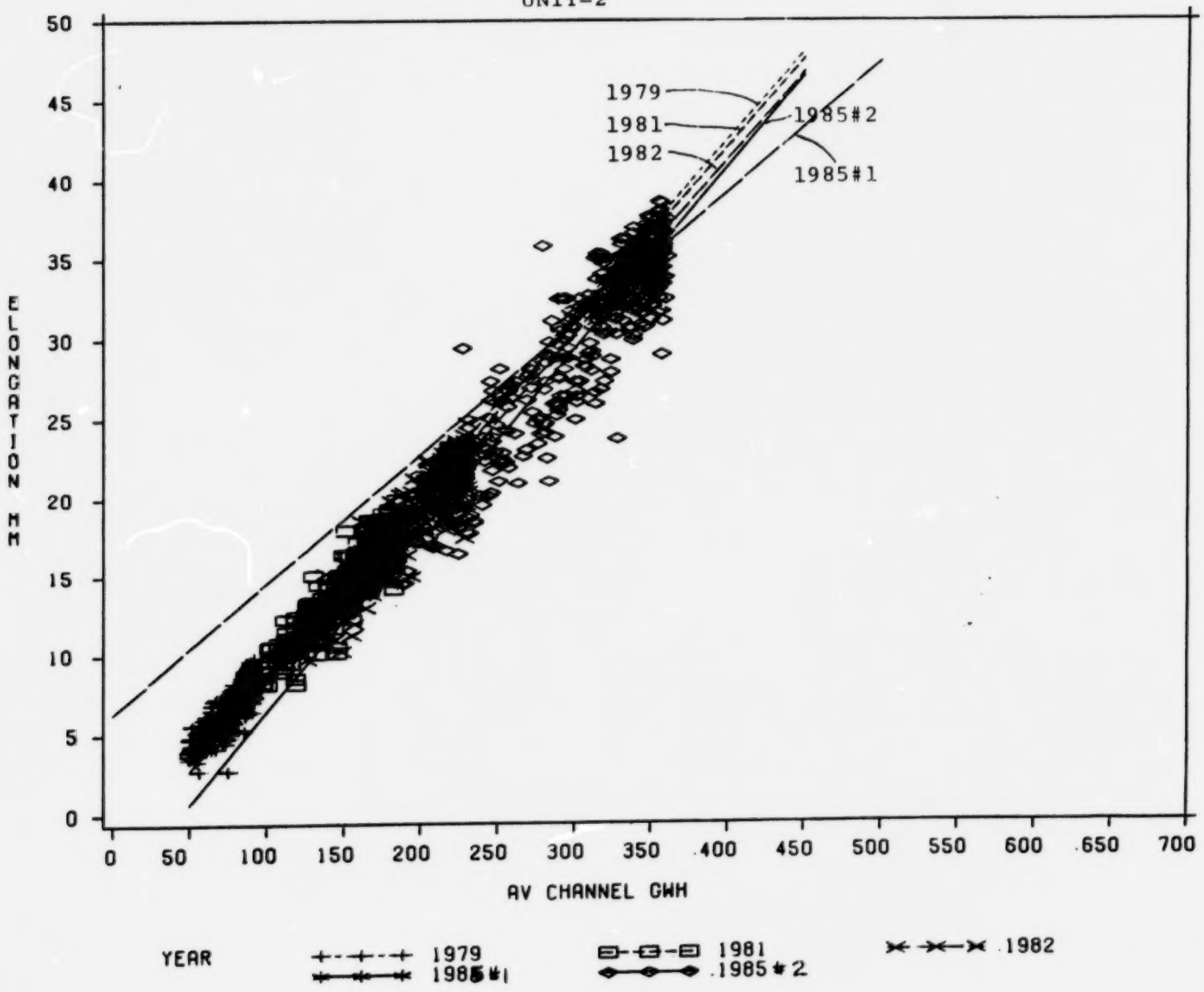

FIGURE 15
BRUCE - A ELONGATION DATA
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UNIT=3

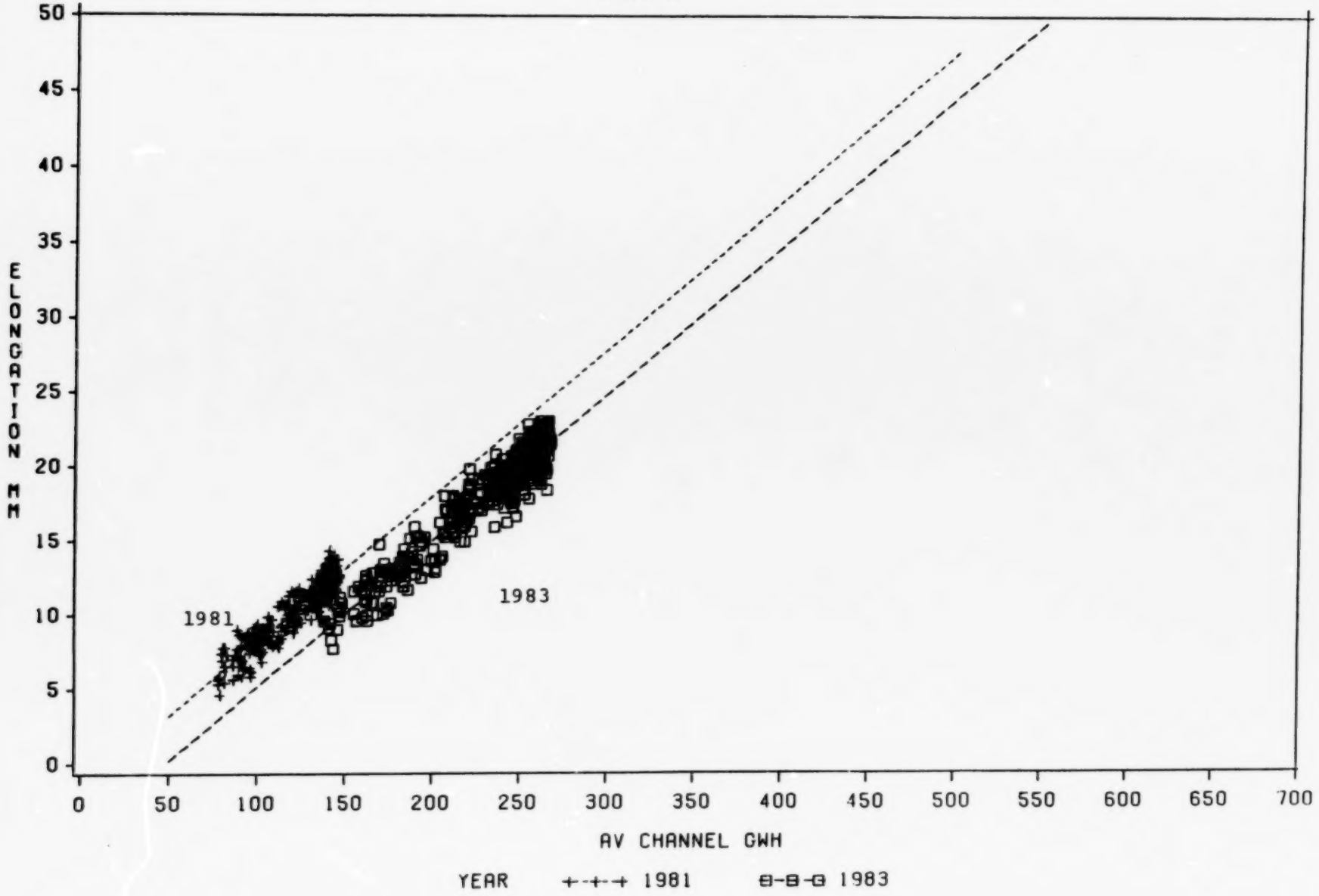

FIGURE 16

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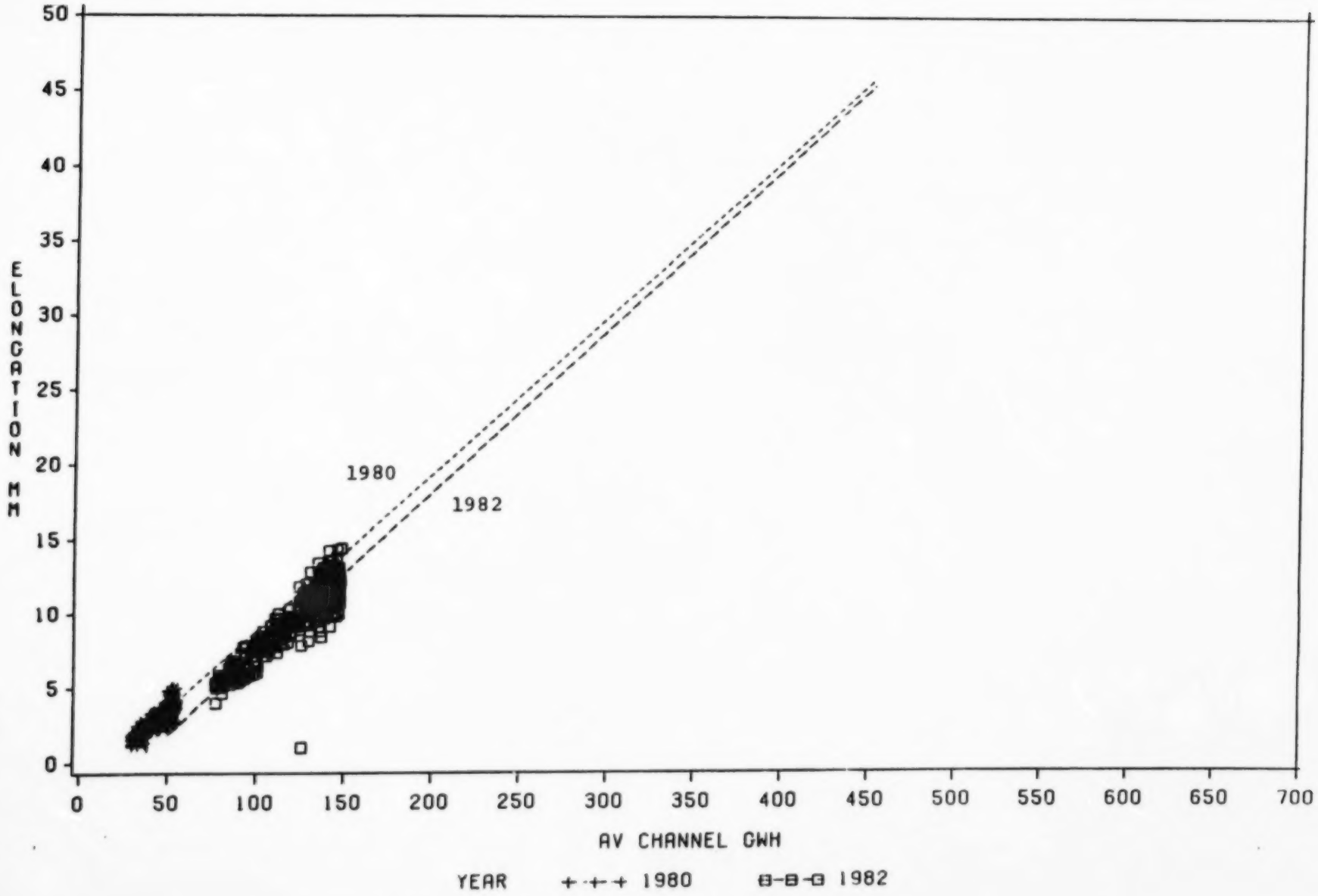

FIGURE 17

BRUCE-A BULK ELONGATION DATA
AVERAGED WITHIN 10 CWH BAND WIDTHS
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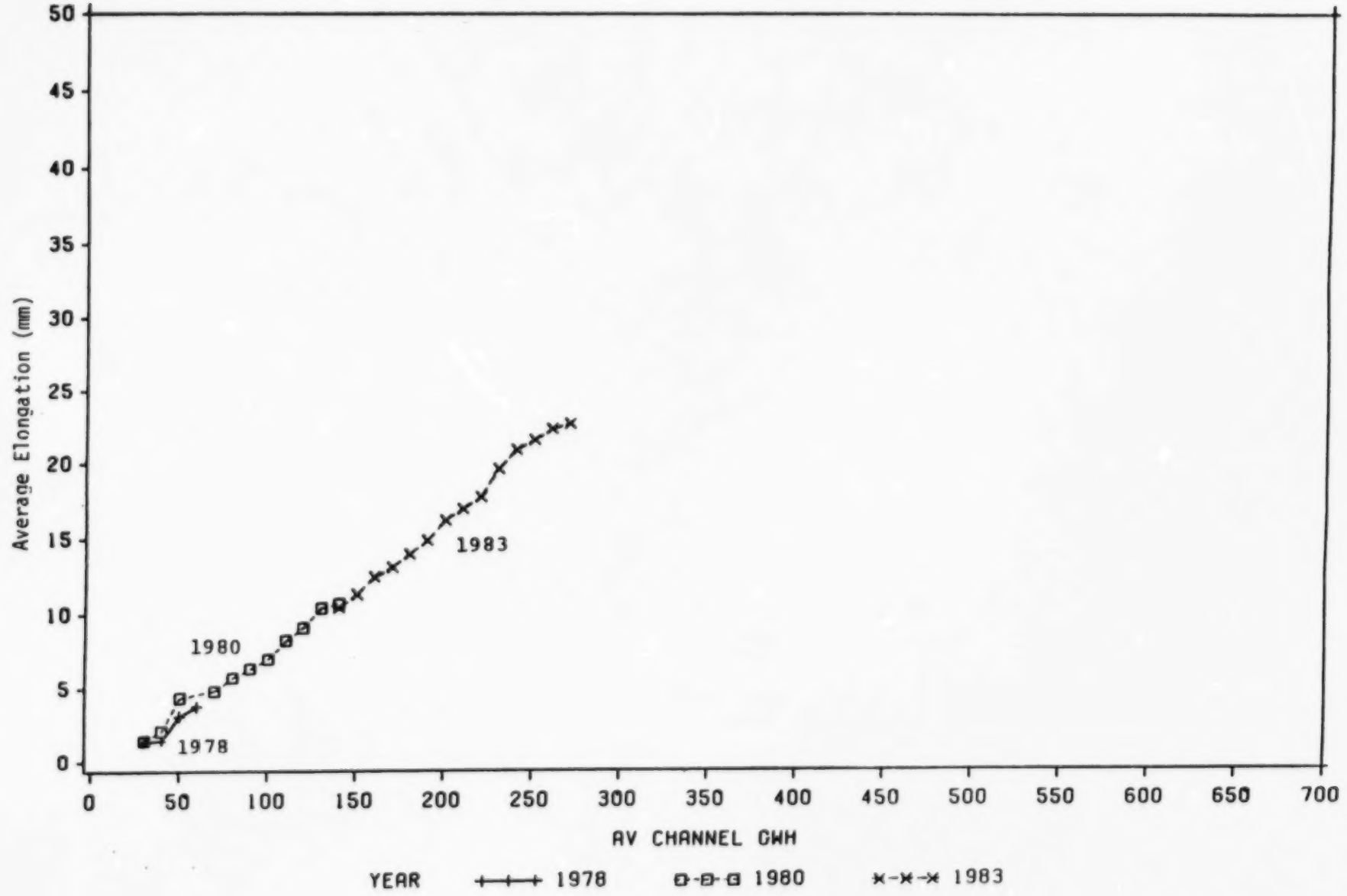

FIGURE 18

BRUCE-A BULK ELONGATION DATA
AVERAGED WITHIN 10 GWH BAND WIDTHS
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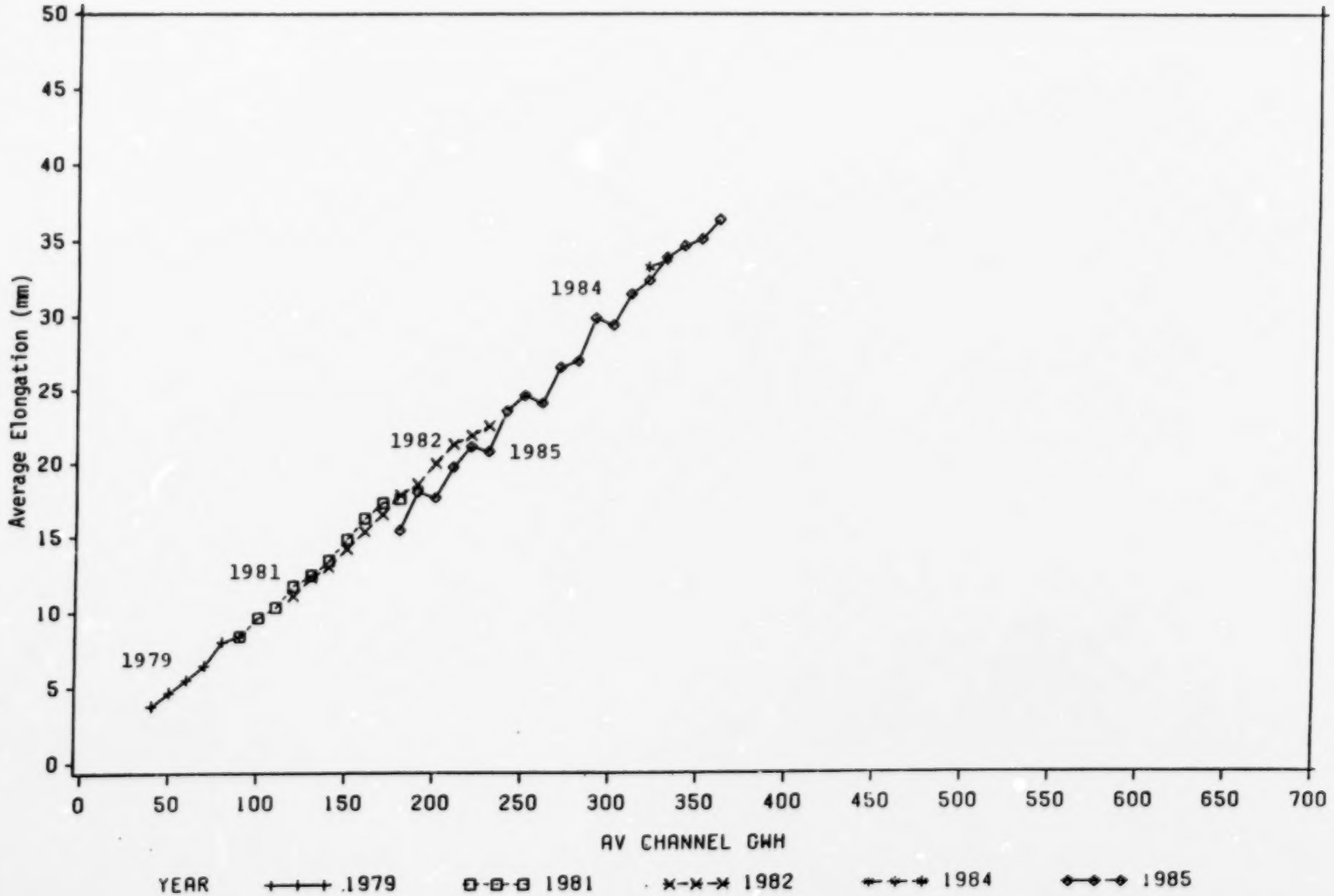

FIGURE 15

BRUCE-A BULK ELONGATION DATA
AVERAGED WITHIN 10 GWH BAND WIDTHS
UNIT=3

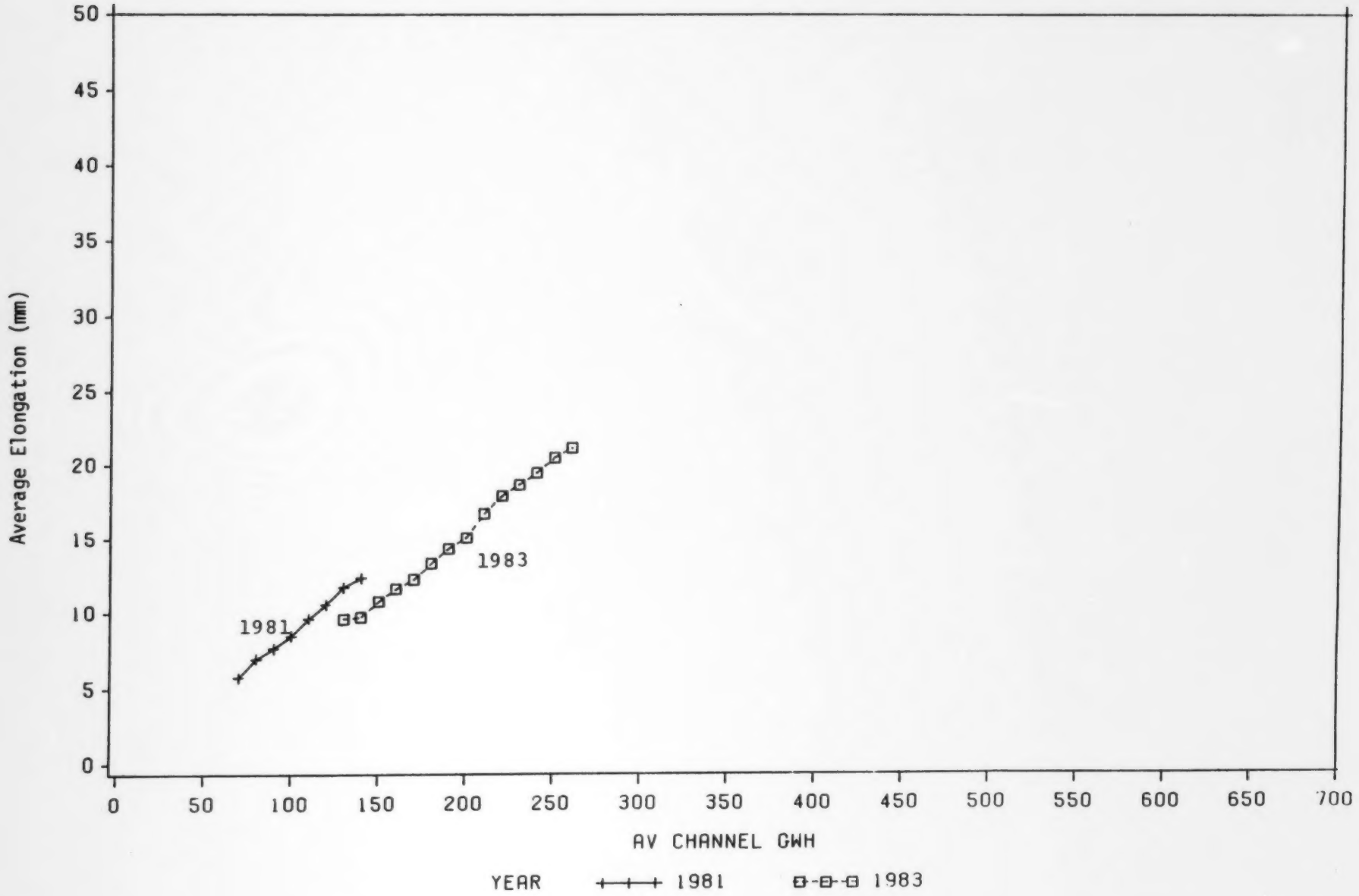

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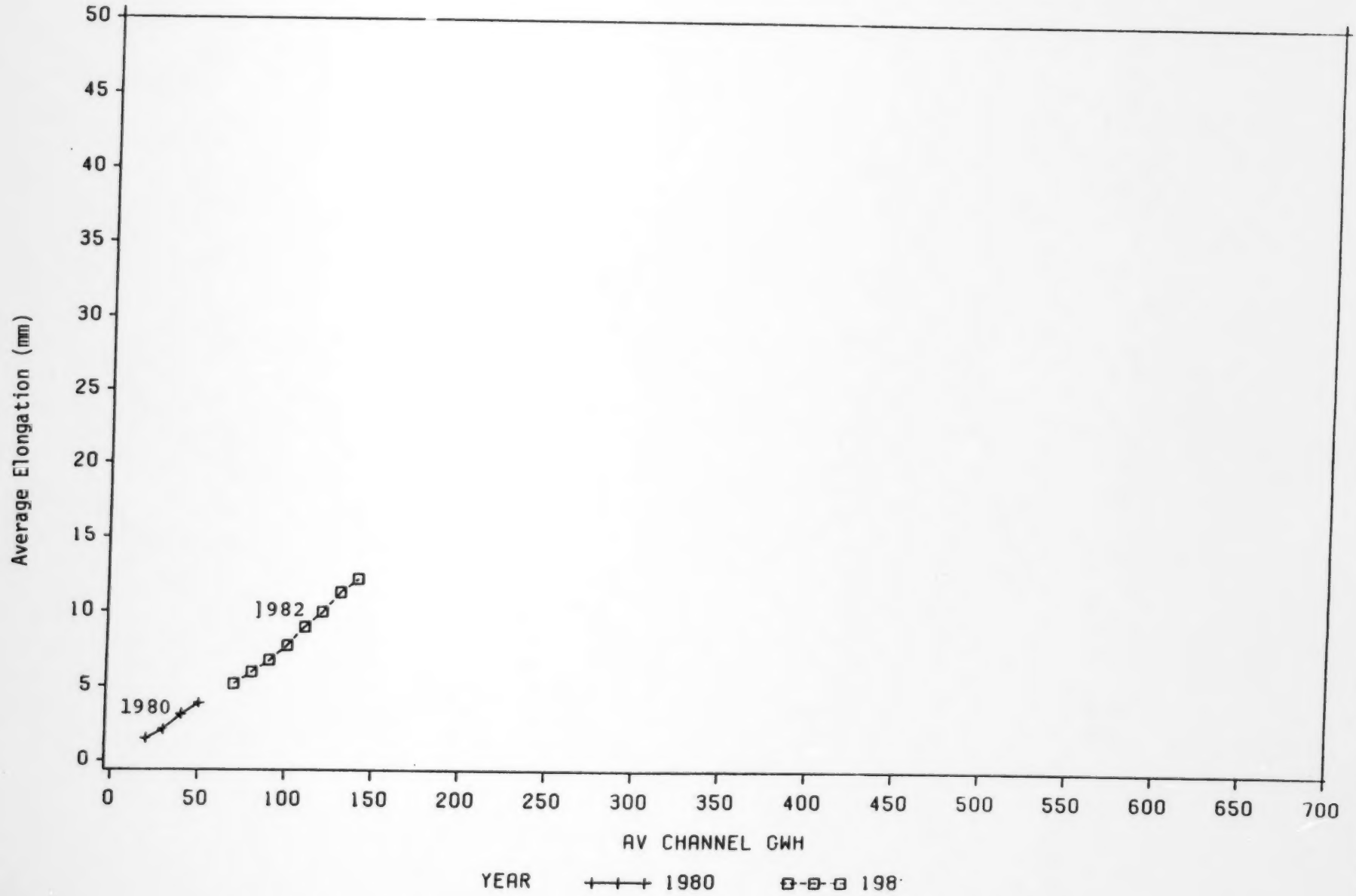
FIGURE
BRUCE-A BULK ELONGATION DATA
AVERAGED WITHIN 10 GWH BAND WIDTHS
UNIT=4



FIGURE

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
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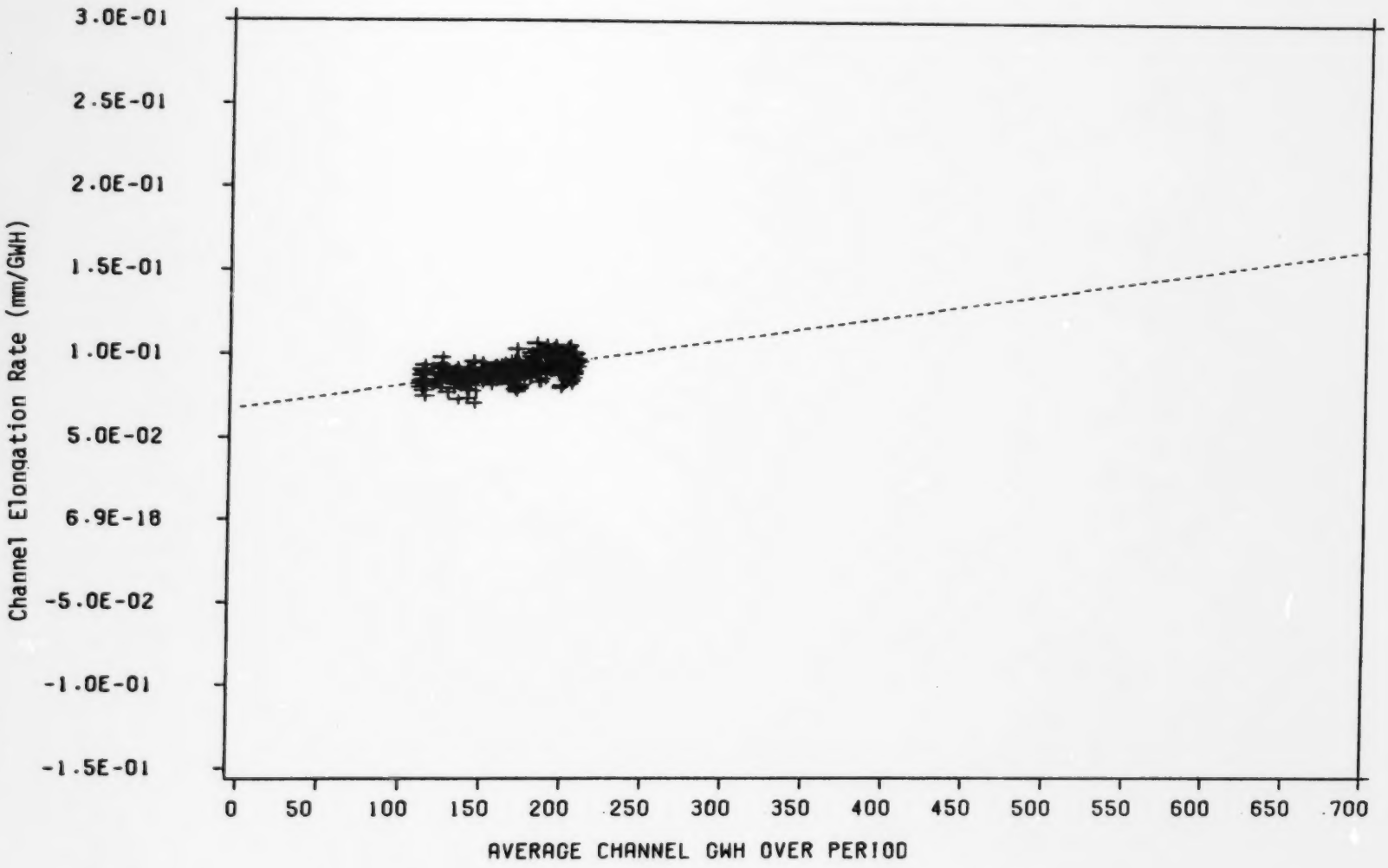

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FIGURE 22

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
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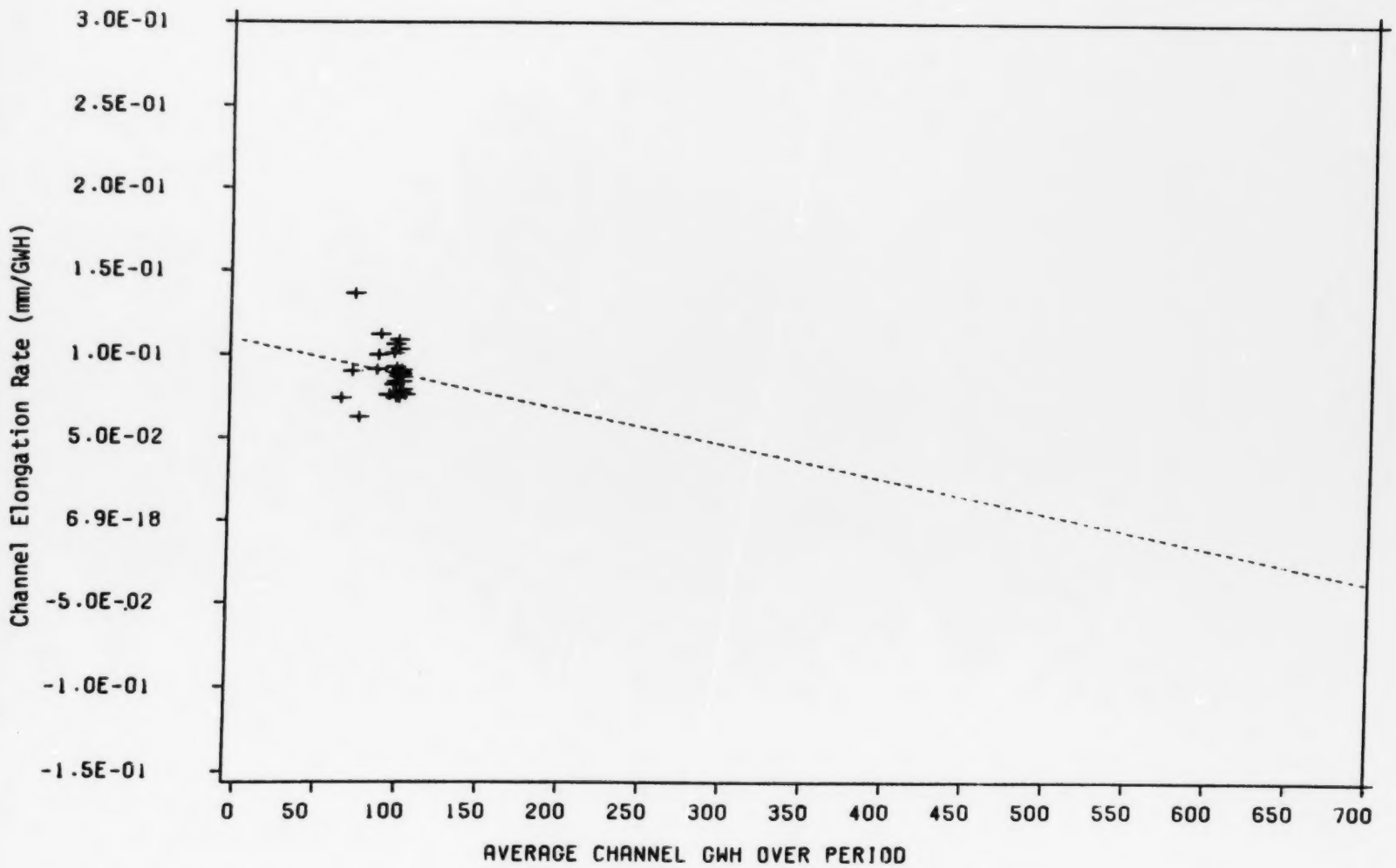

FIGURE 3

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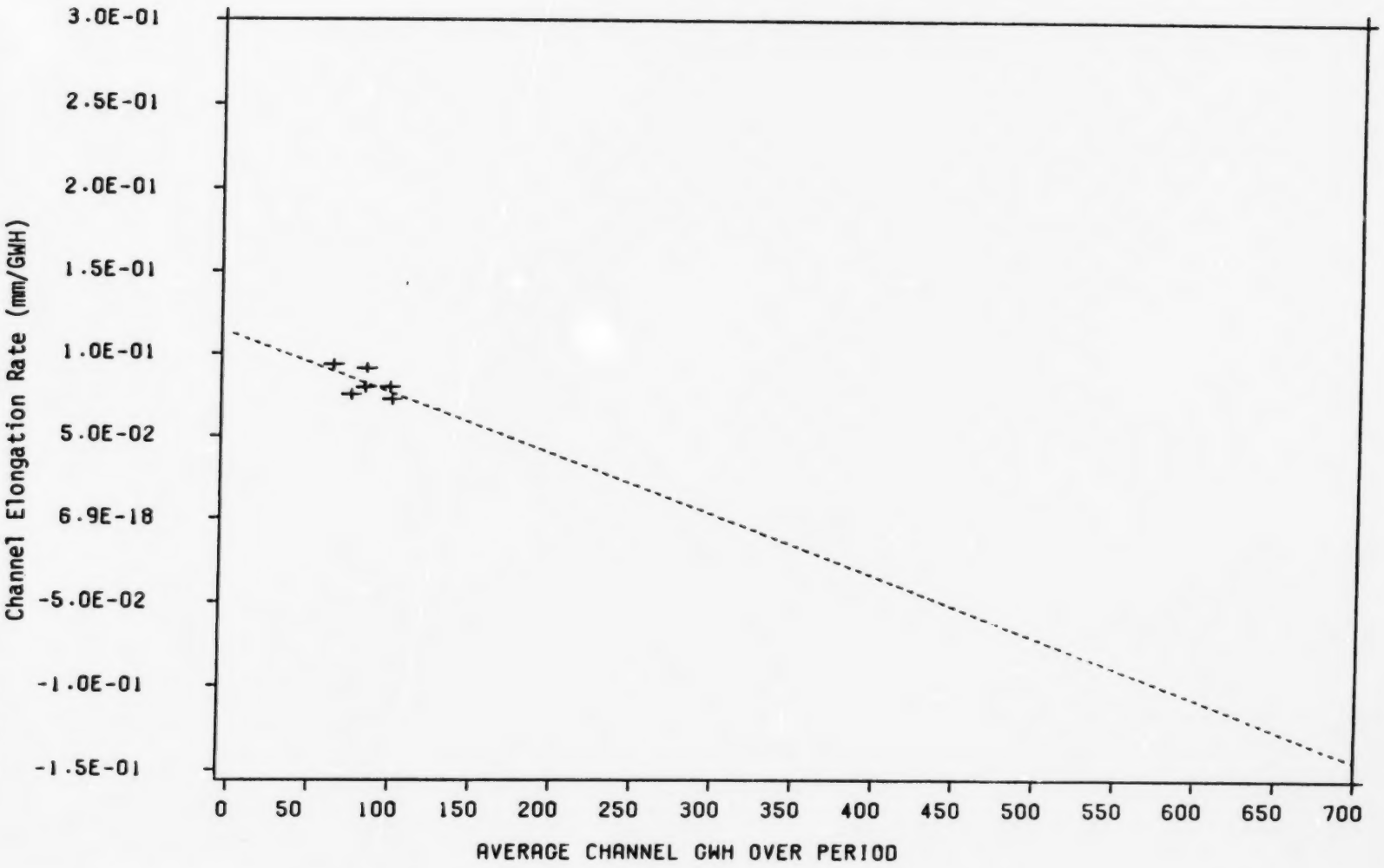

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FIGURE 2.

BRUCE—A ELONGATION DATA

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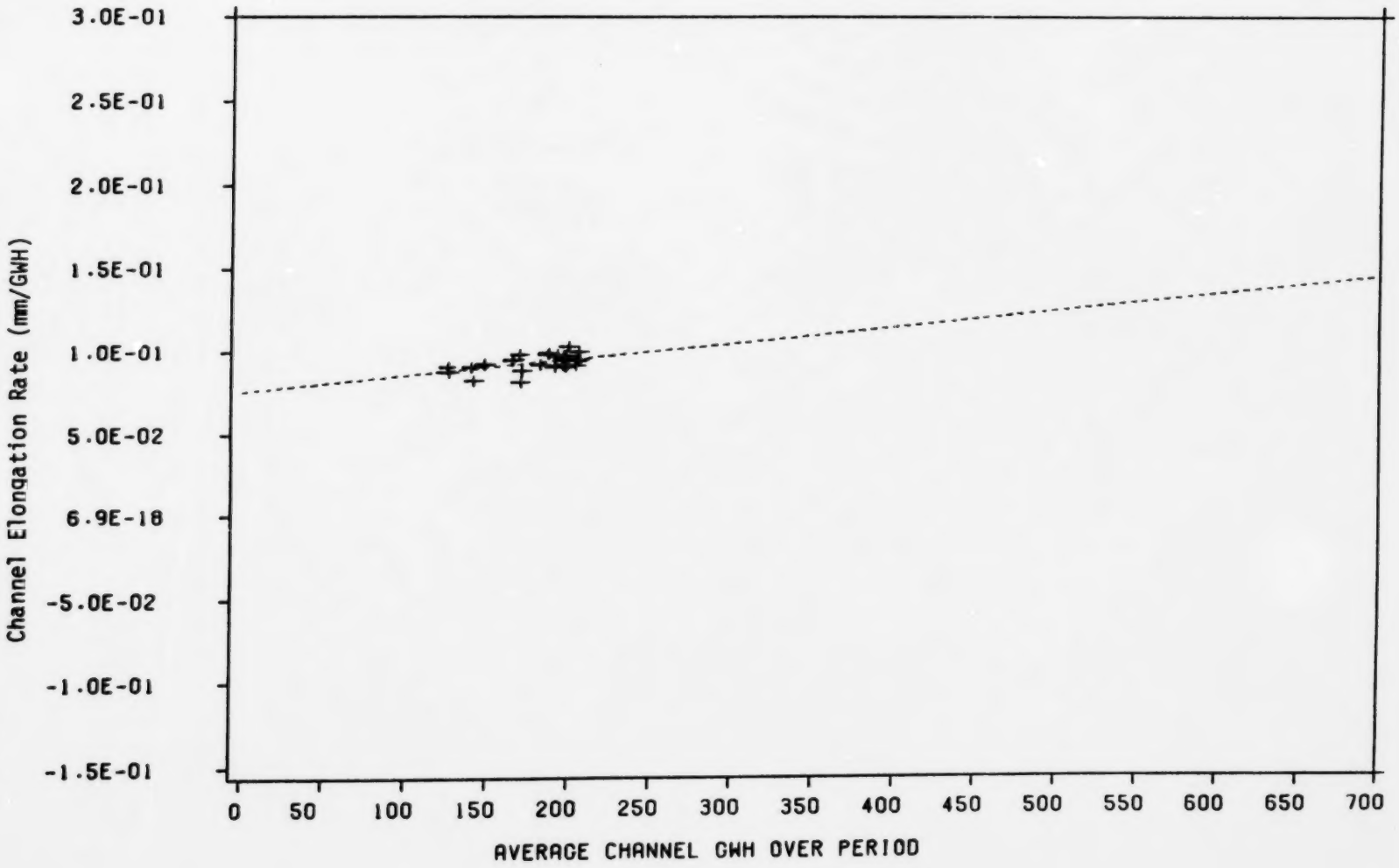

FIGURE 25

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
MASK=1 UNIT=2 PERIOD=1979-1981

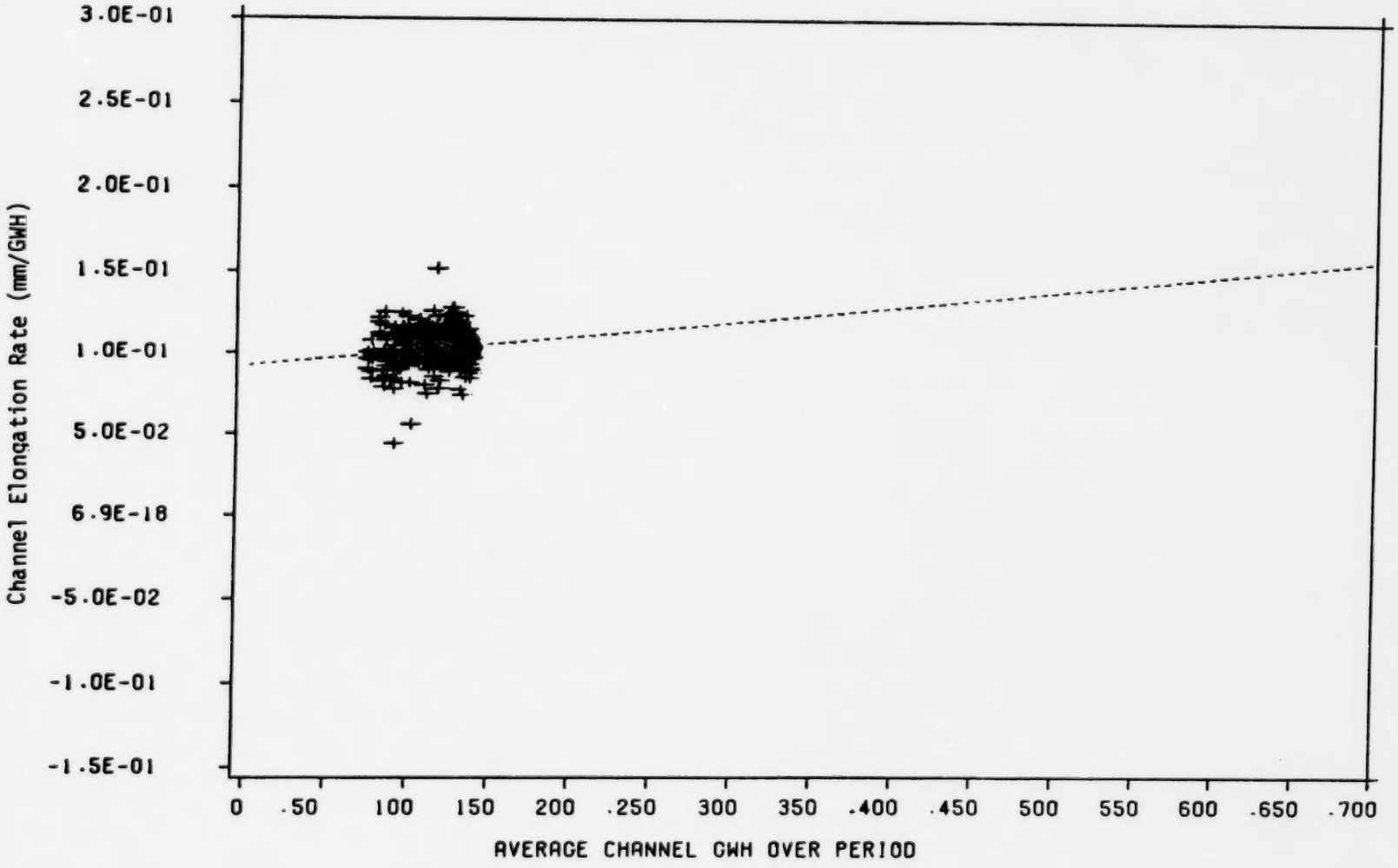

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FIGURE 26

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
MASK=1 UNIT=2 PERIOD=1981-1982

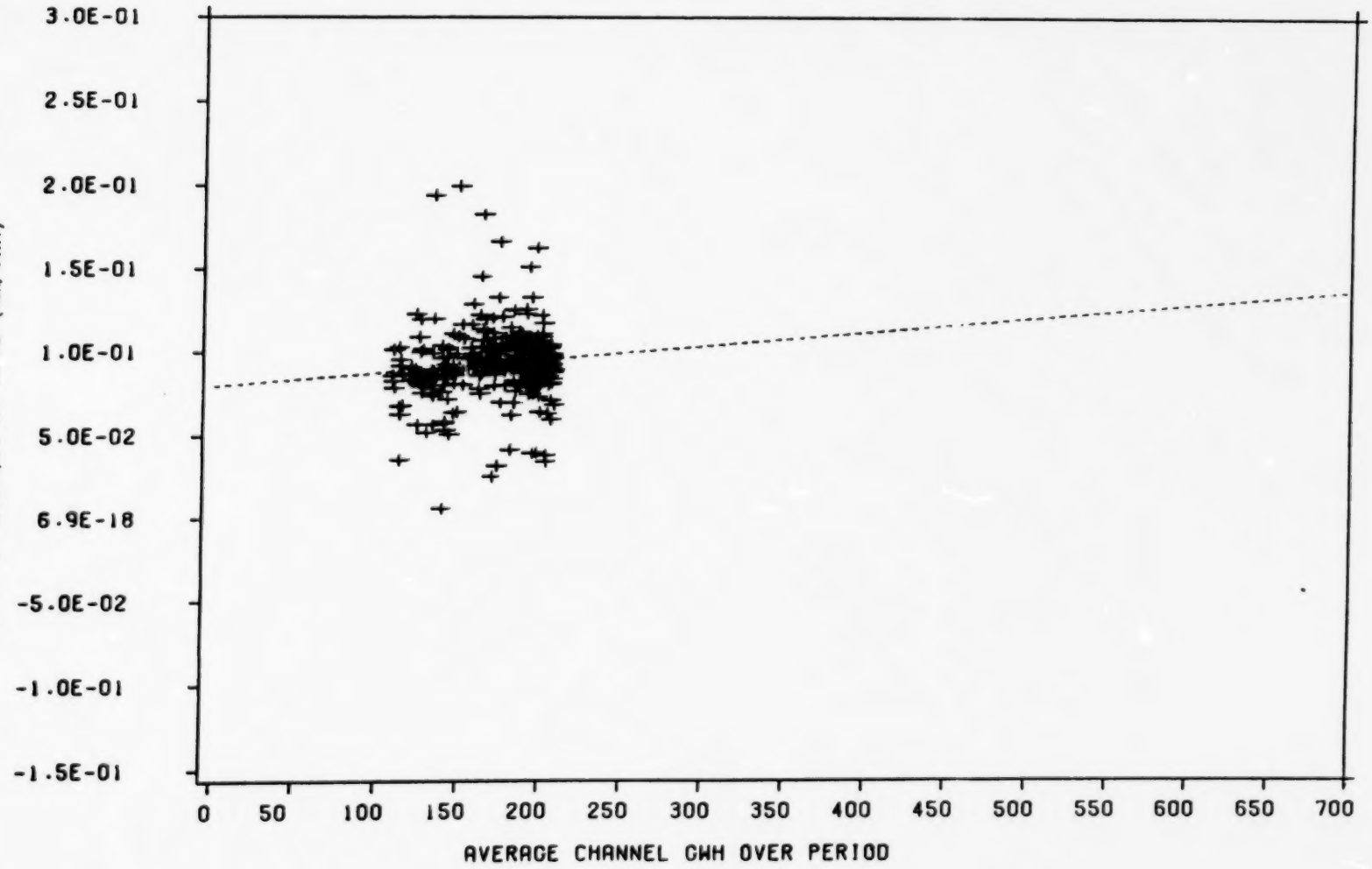

FIGURE 27

BRUCE-A ELONGATION DATA

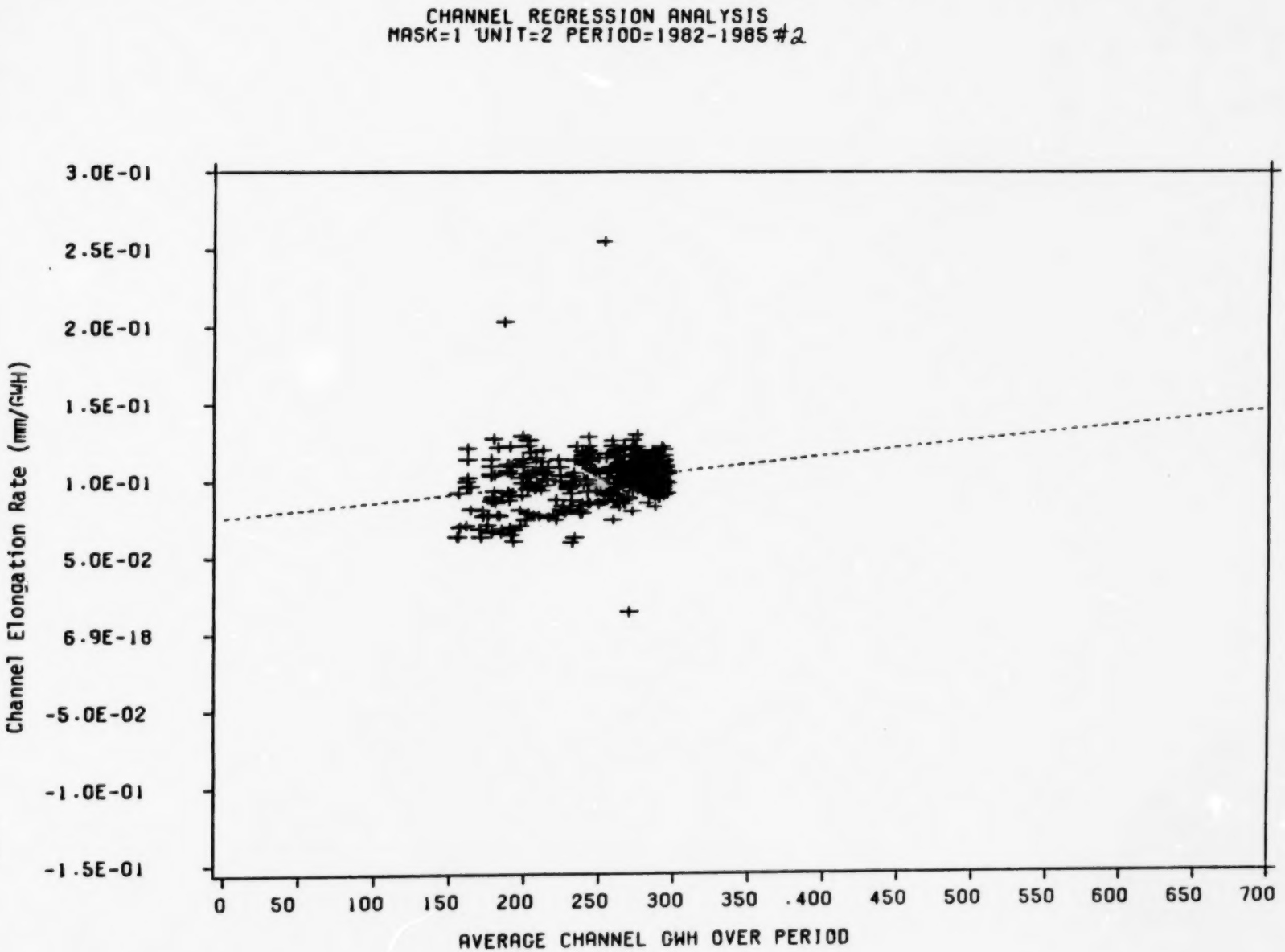

FIGURE 2.7

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
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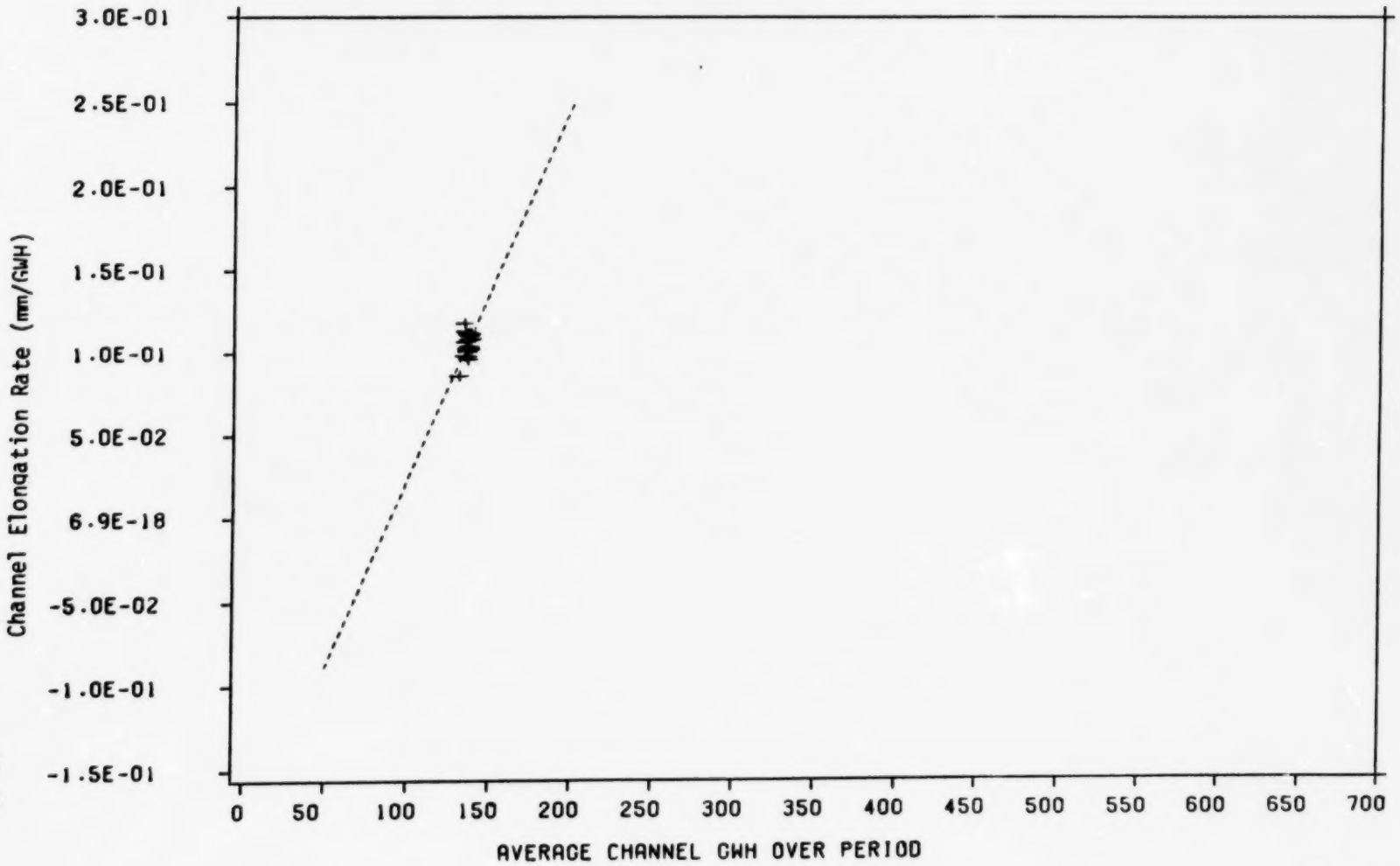

FIGURE 29

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
MASK=2 UNIT=2 PERIOD=1981-1982

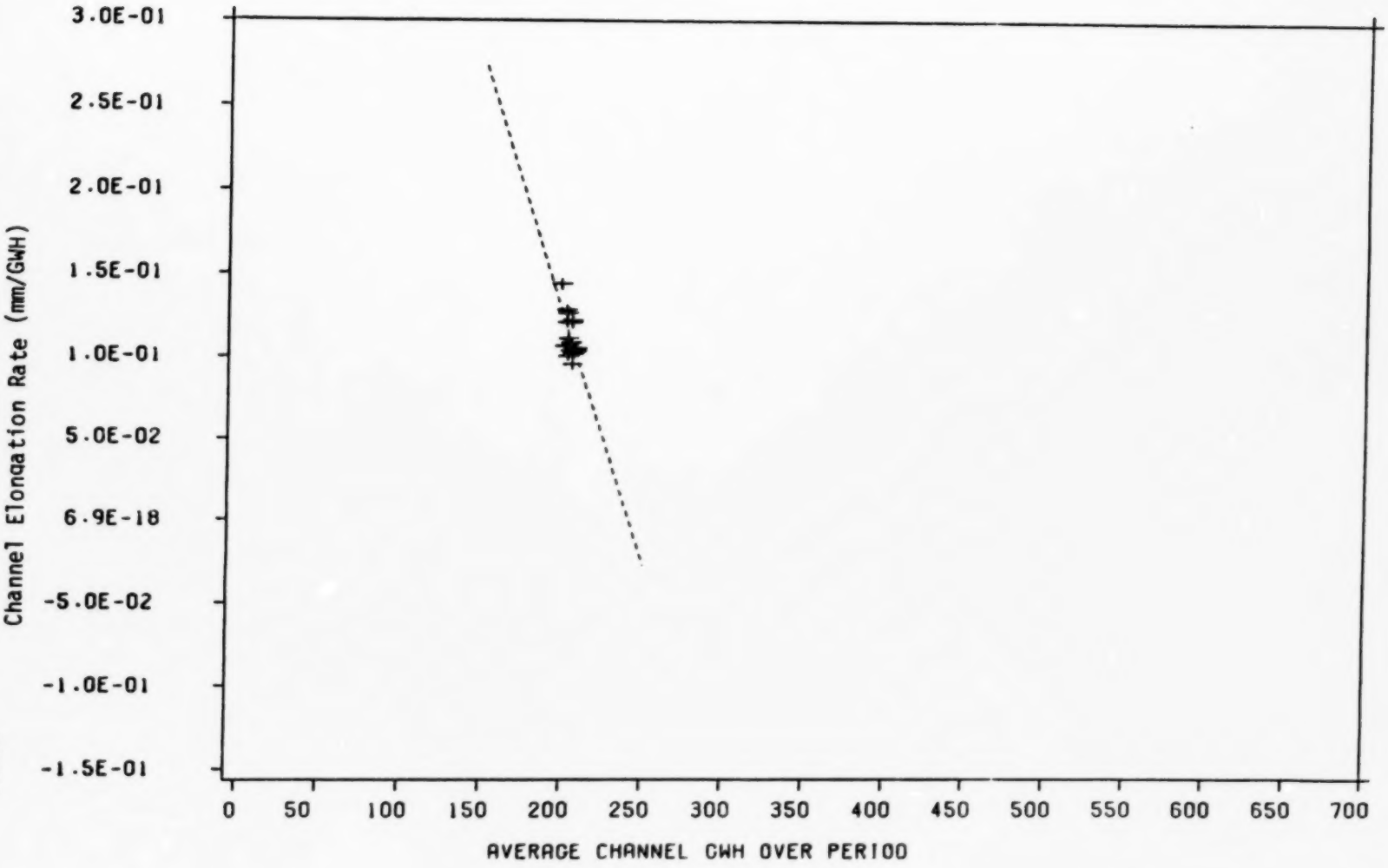

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FIGURE 30

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
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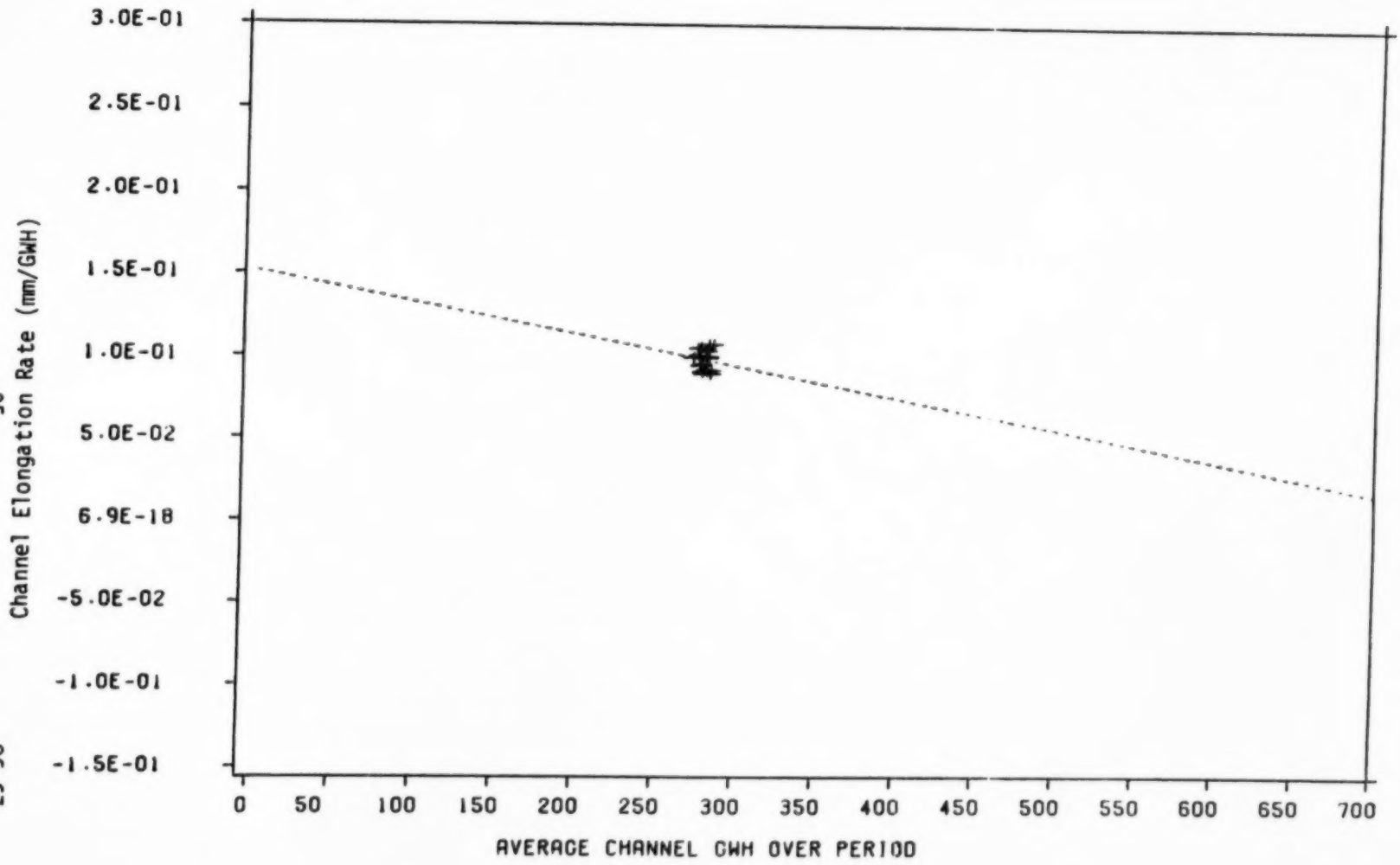

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FIGURE 3E

BRUCE—A ELONGATION DATA

CHANNEL REGRESSION ANALYSIS
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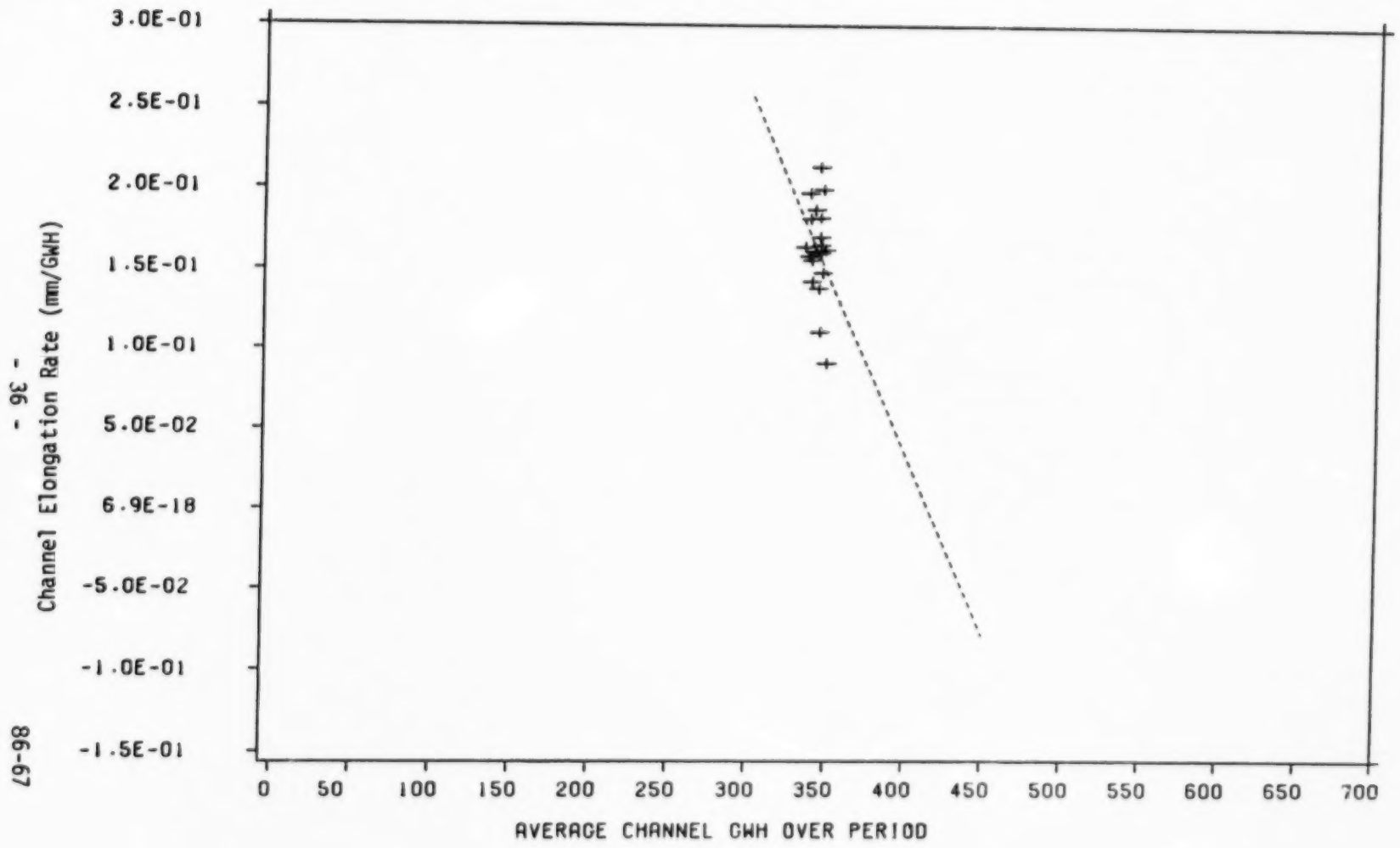

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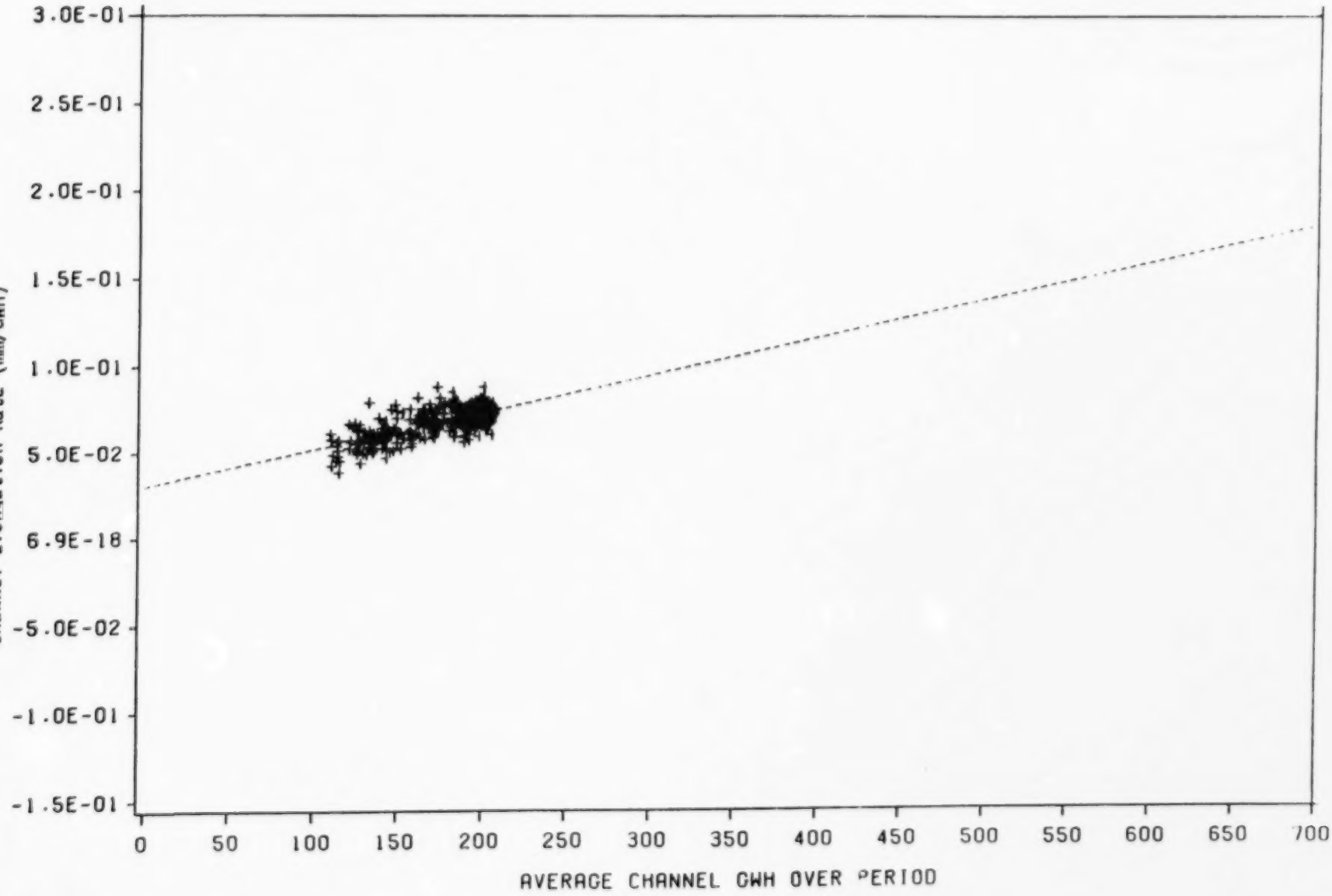
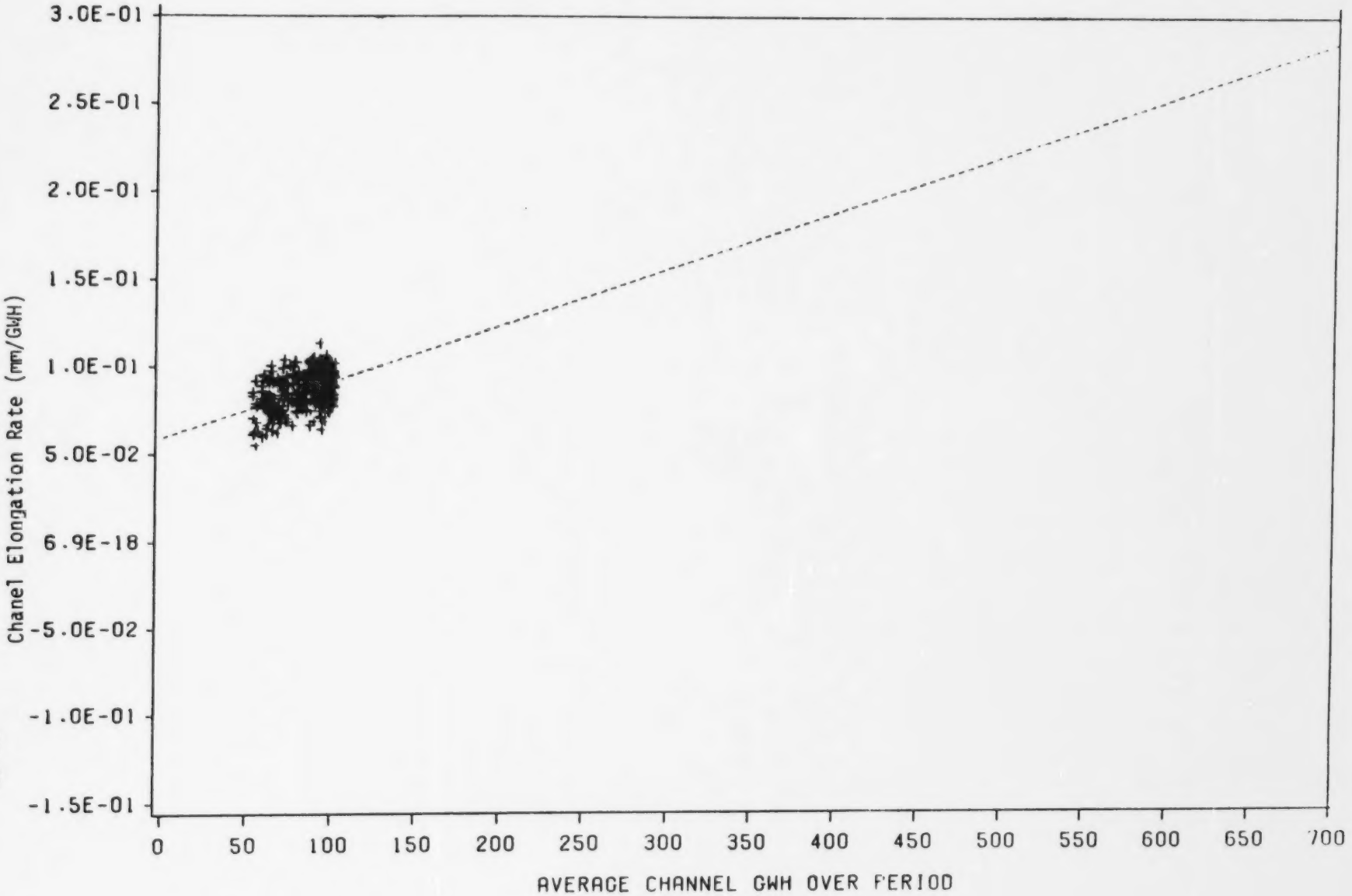
BRUCE-A ELONGATION DATA
CHANNEL REGRESSION ANALYSIS
UNIT=3 PERIOD=1981-1983



86-67

FIGURE 33

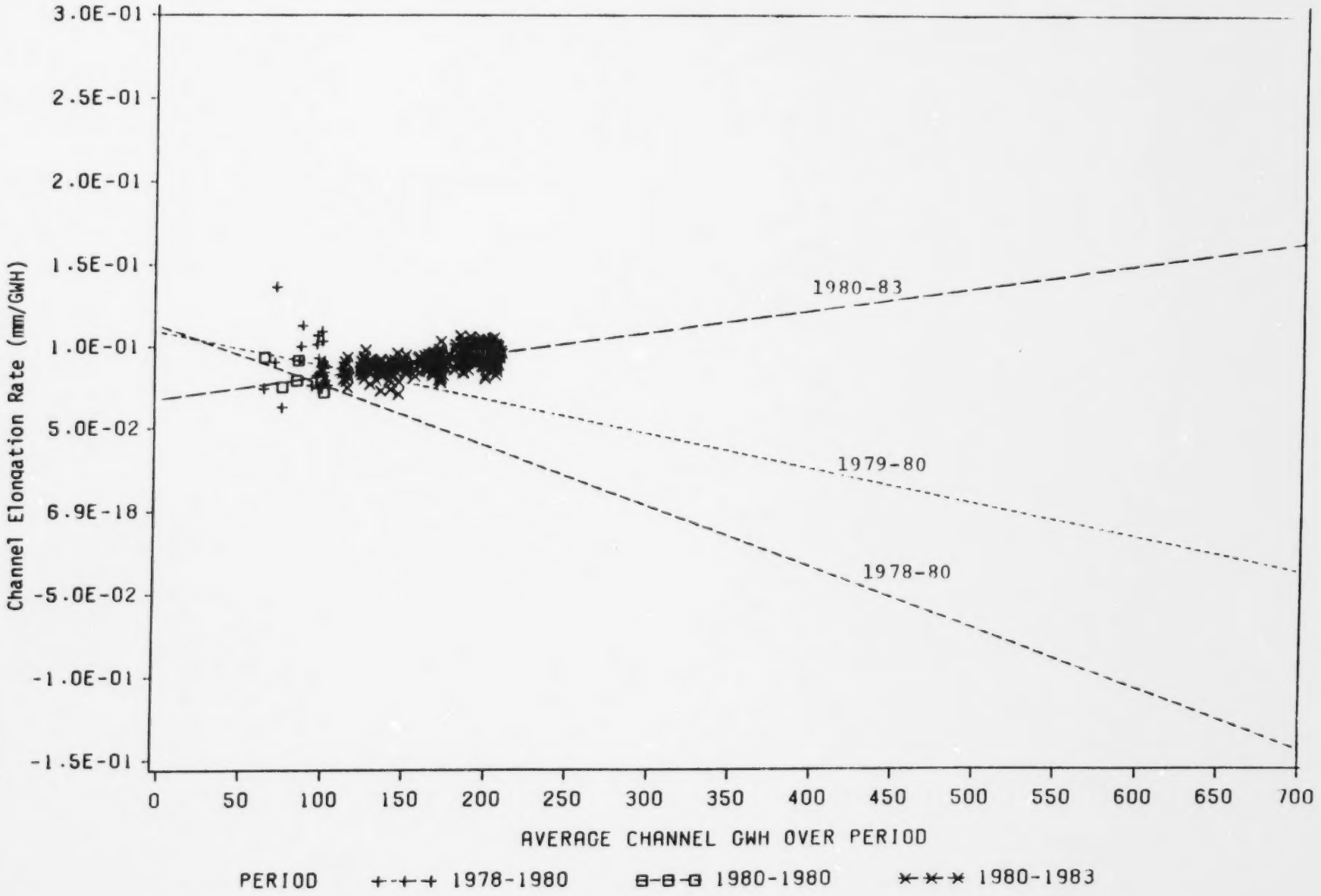
BRUCE-A ELONGATION DATA
CHANNEL REGRESSION ANALYSIS
UNIT=4 PERIOD=1980-1982



86-67

FIGURE

BRUCE-A ELONGATION DATA
CHANNEL ELONGATIONS
UNIT=1

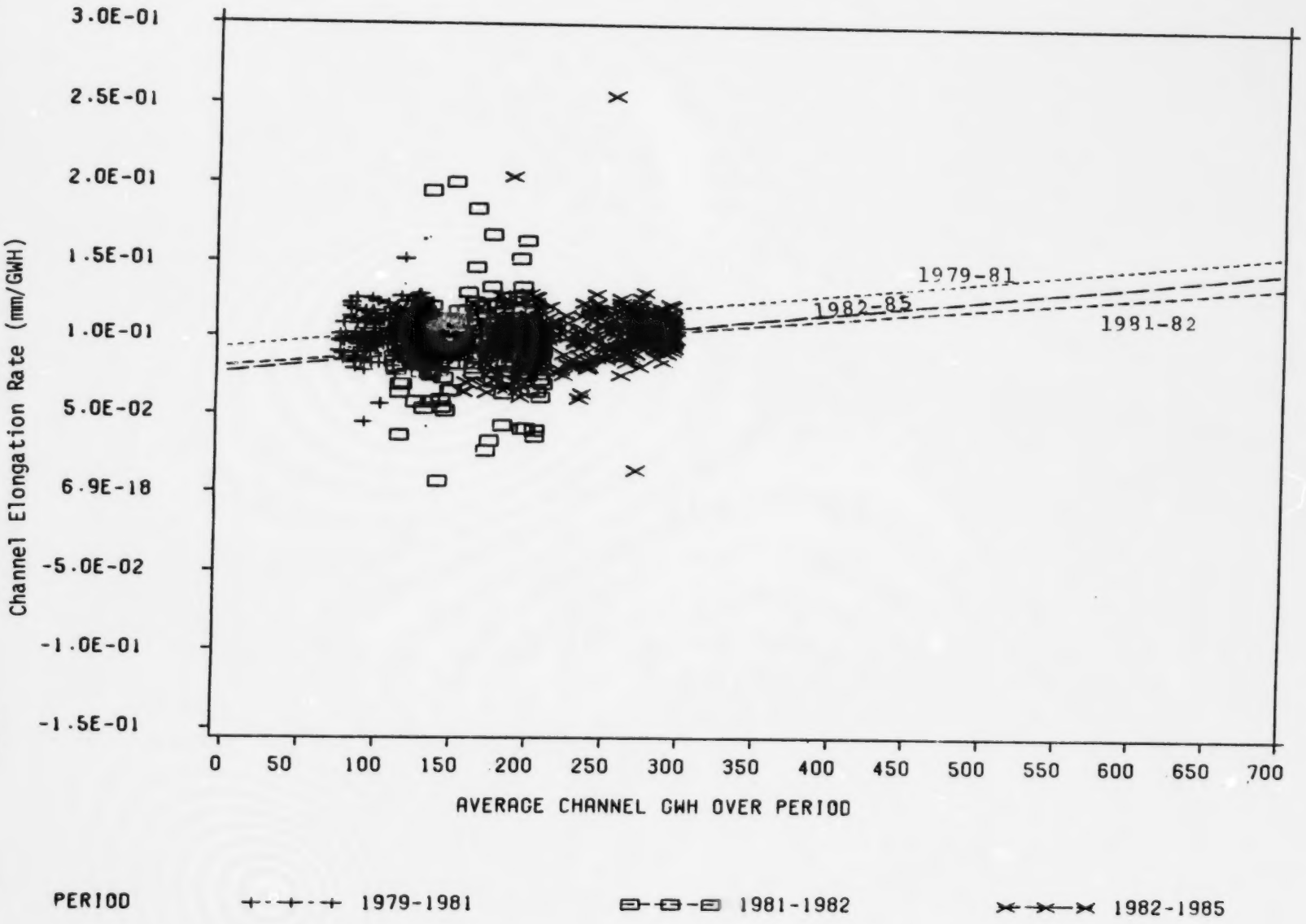


86-67

FIGURE 35

BRUCE—A ELONGATION DATA

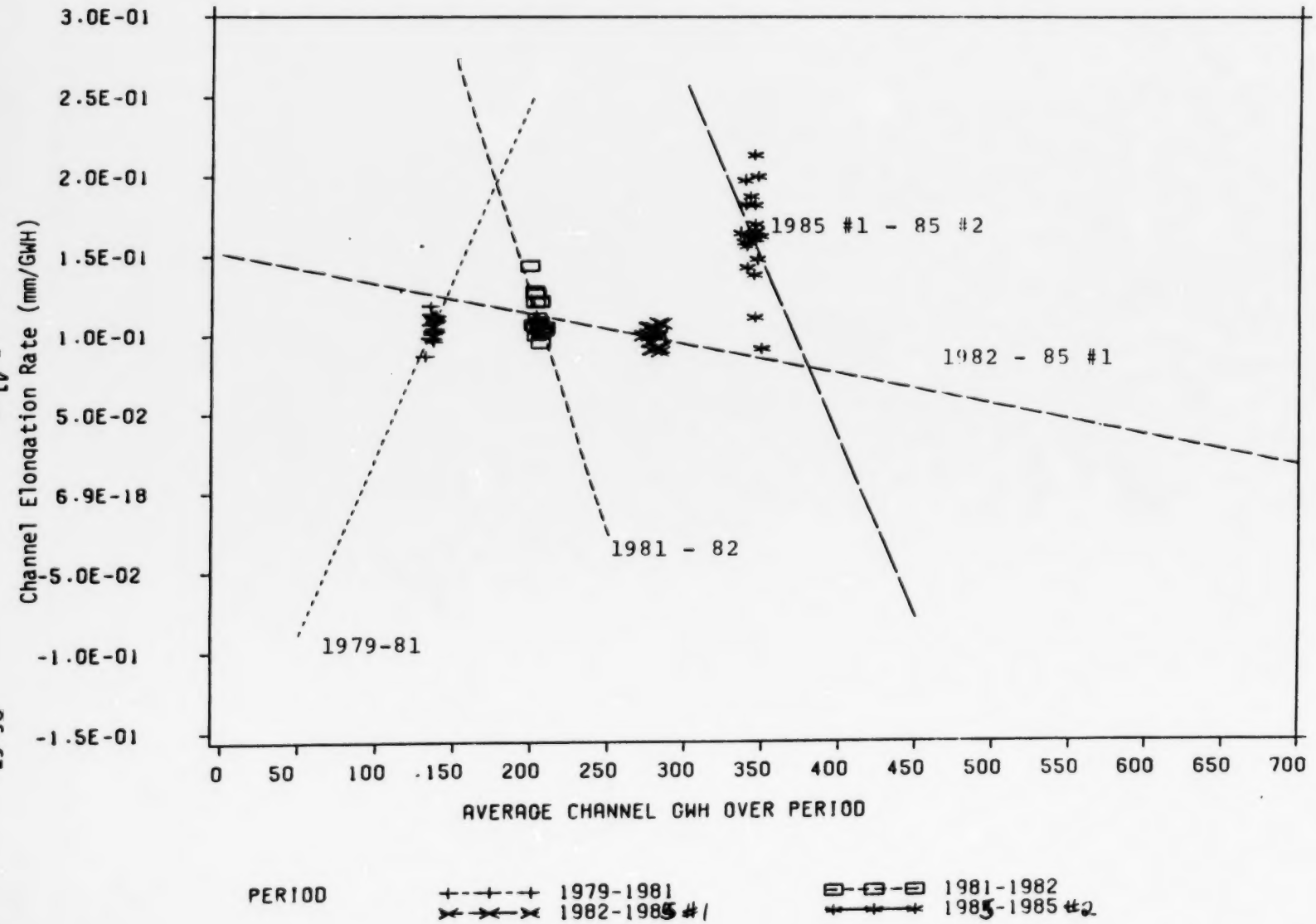
CHANNEL ELONGATIONS
MASK=1 UNIT=2



86-67

BRUCE—A ELONGATION DATA

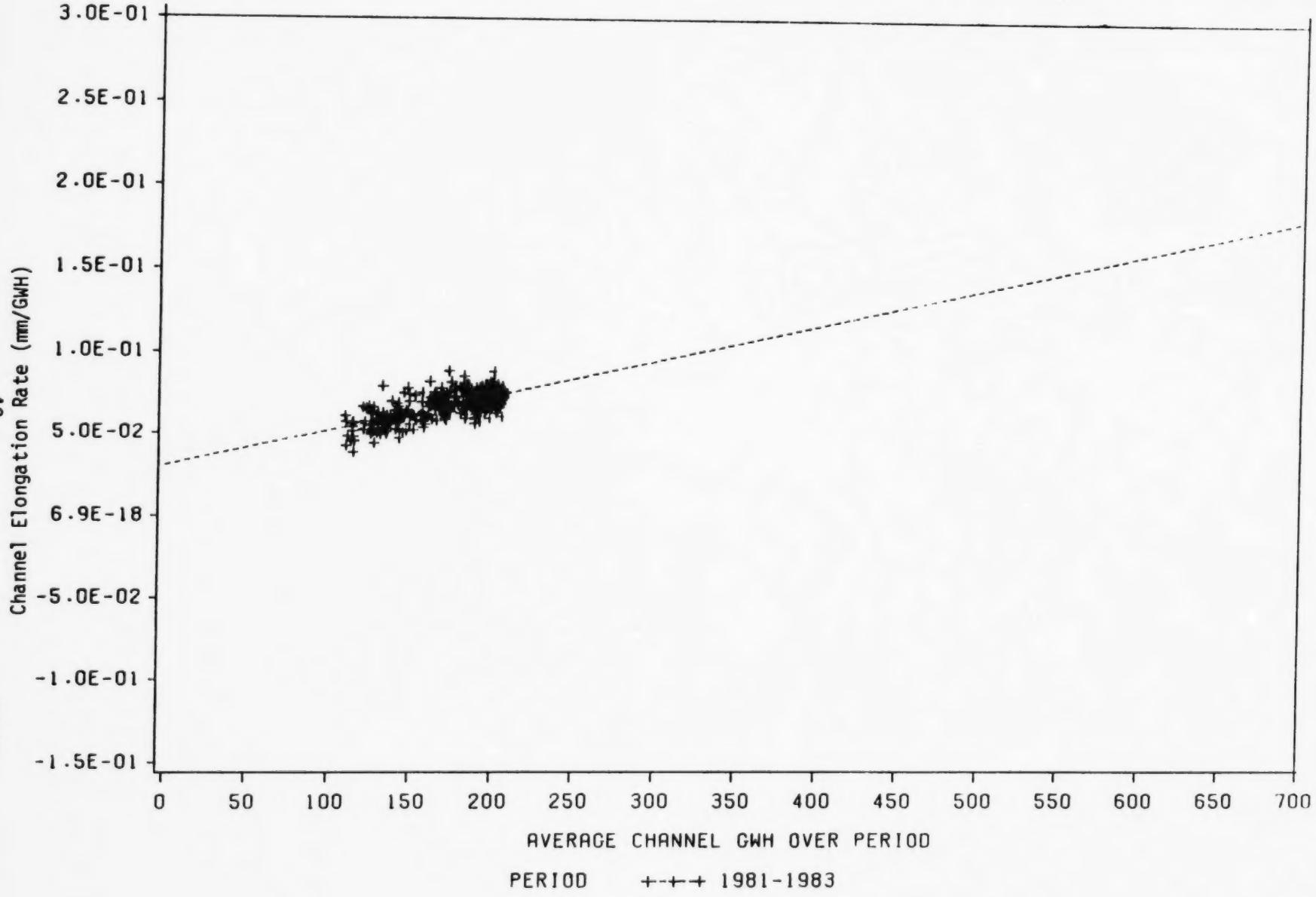
CHANNEL ELONGATIONS
MASK=2 UNIT=2



86-67

FIGURE 37

BRUCE-A ELONGATION DATA
CHANNEL ELONGATIONS
UNIT=3



BRUCE-A ELONGATION DATA
CHANNEL ELONGATIONS
UNIT=4

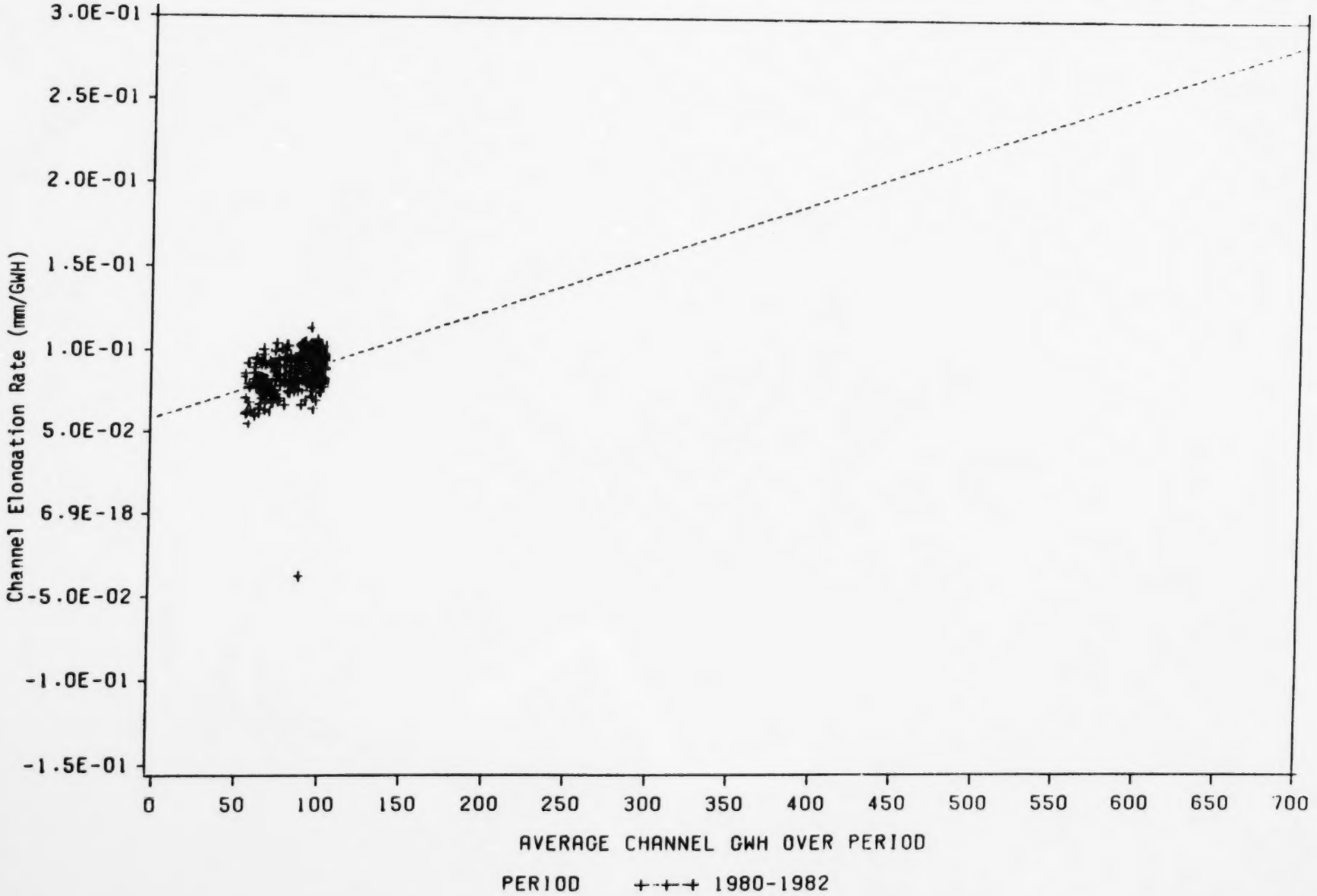


FIGURE 39

BRUCE-A CHANNEL ELONGATION RATES
AVERAGED WITHIN 10 GWH BAND WIDTHS
UNIT=1

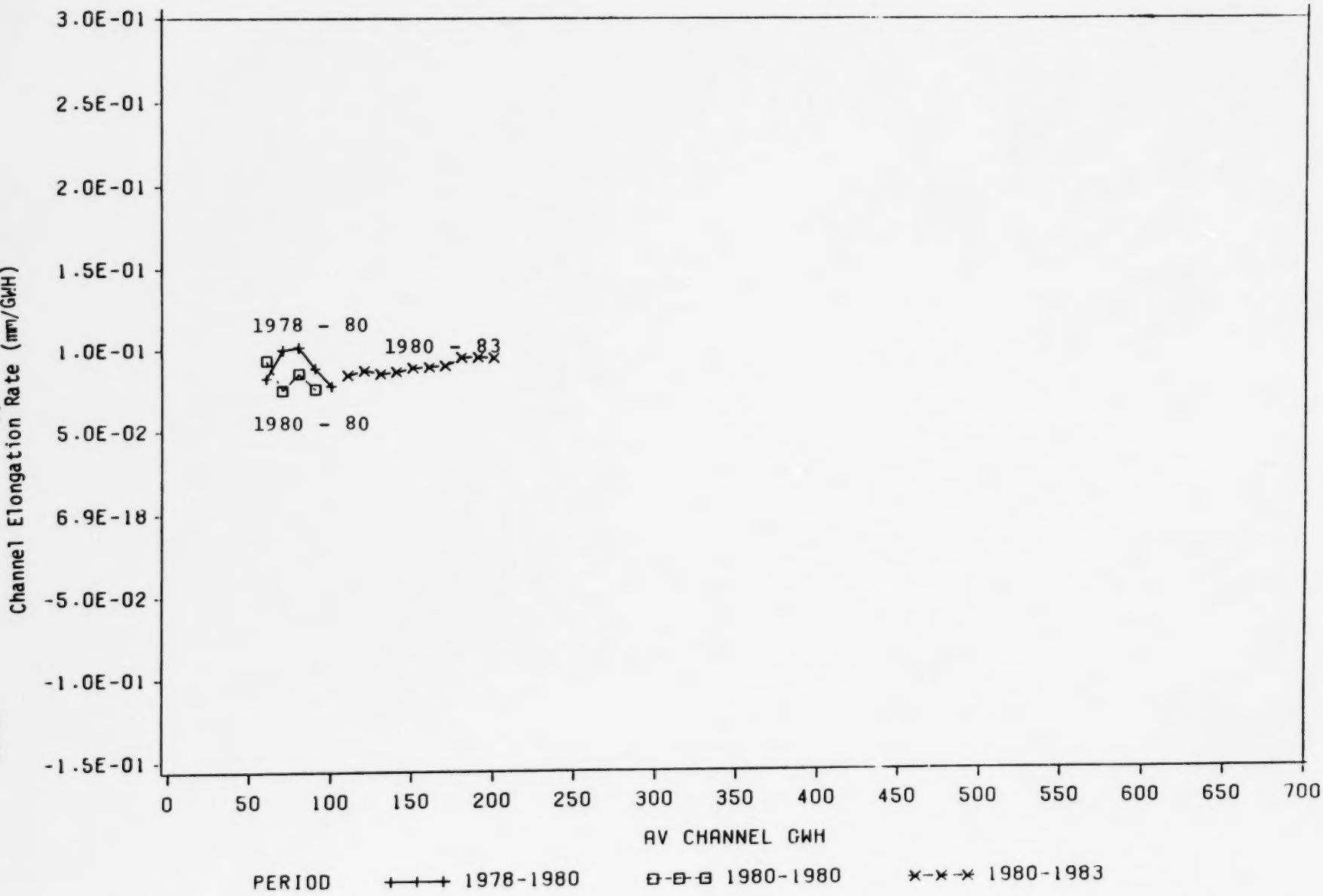
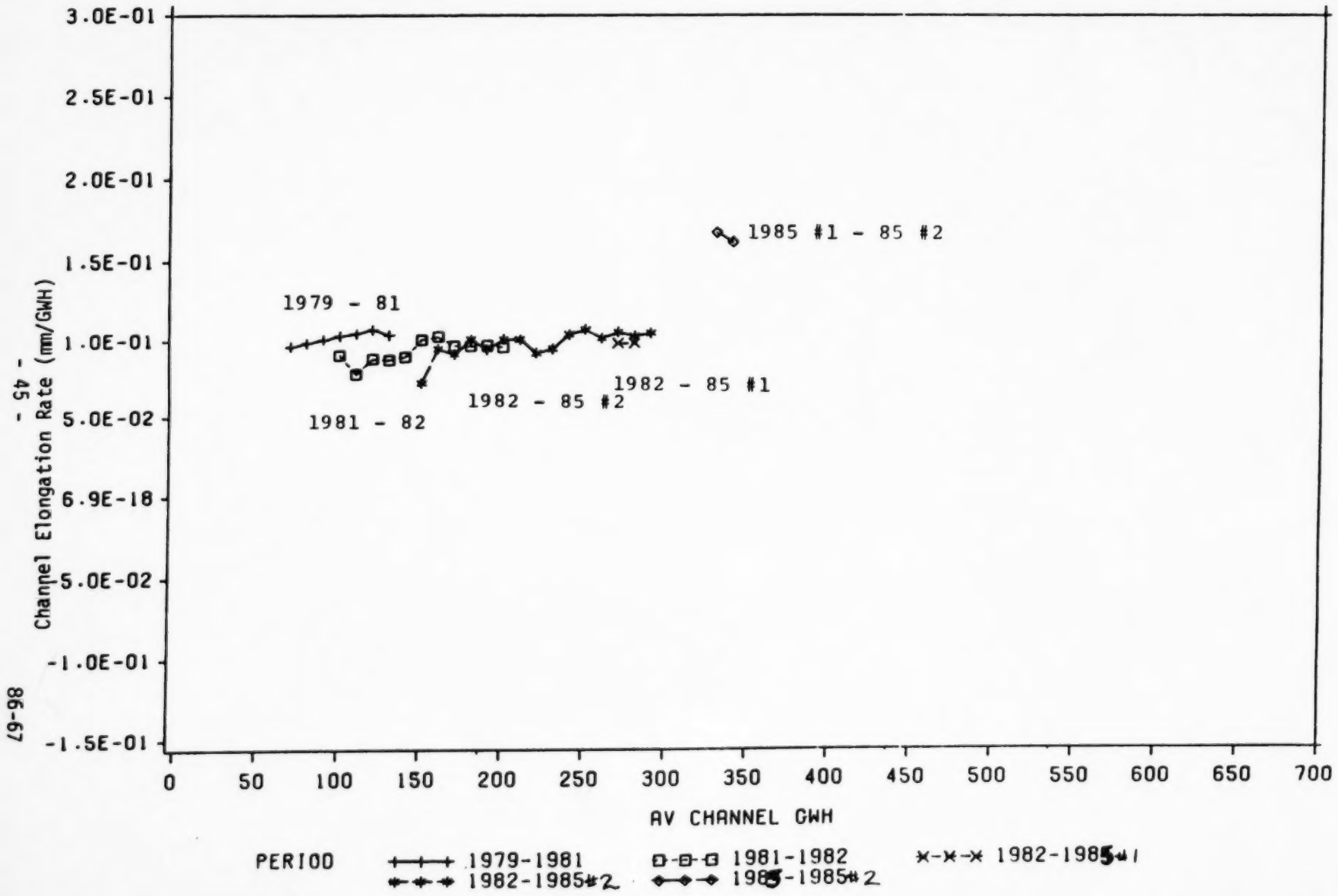
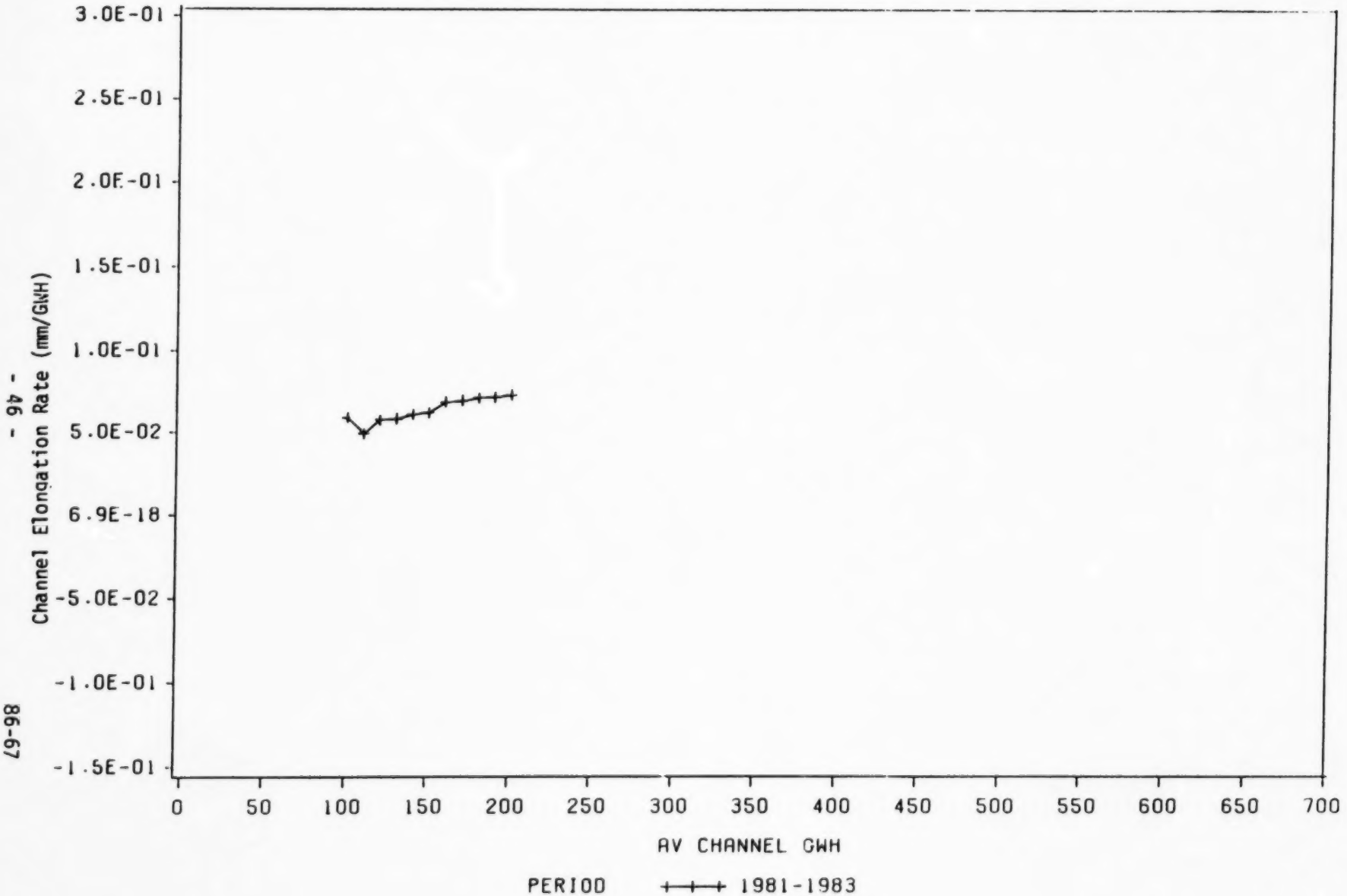


FIGURE 40

BRUCE-A CHANNEL ELONGATION RATES
AVERAGED WITHIN 10 GWH BAND WIDTHS
UNIT=2



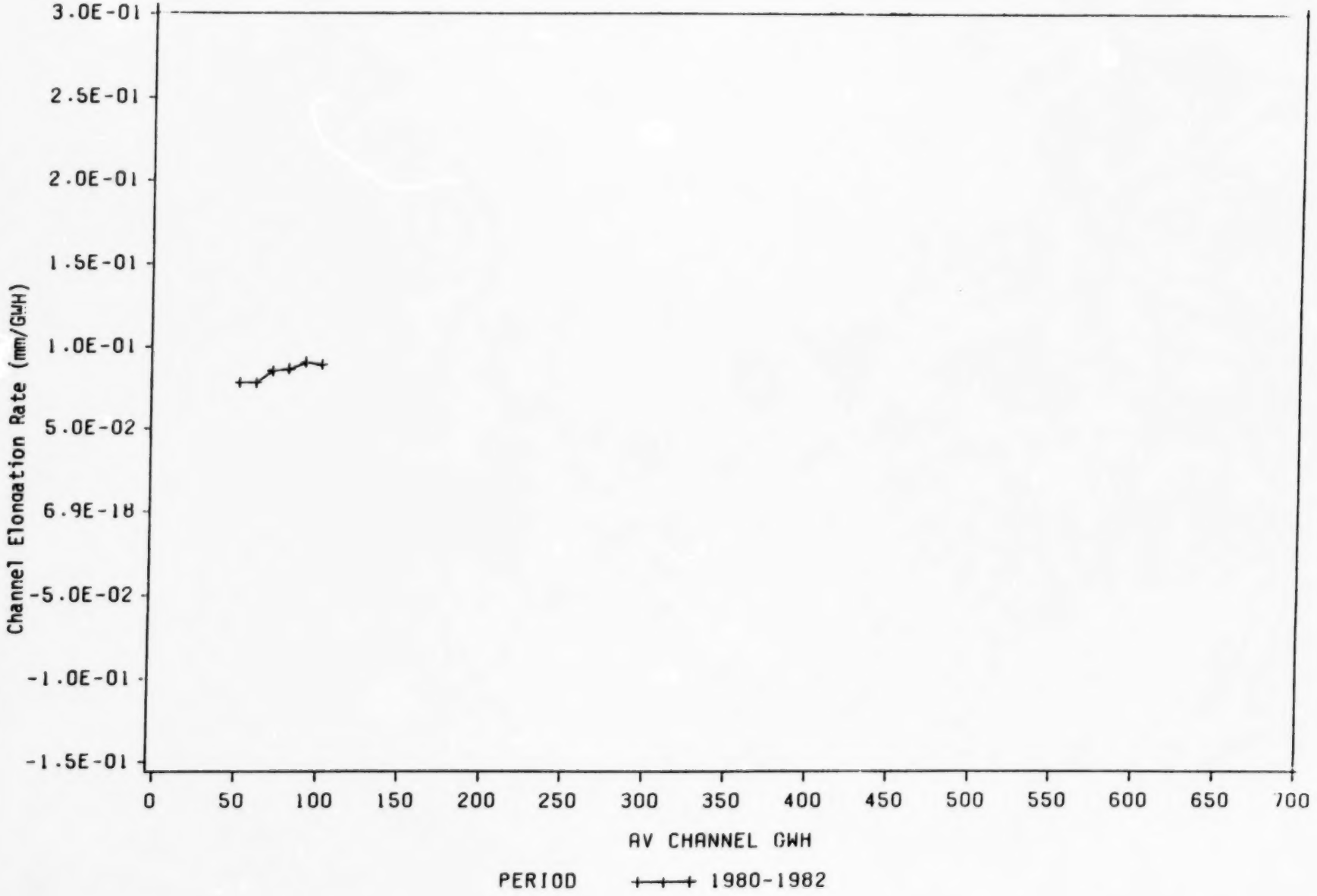
BRUCE-A CHANNEL ELONGATION RATES
AVERAGED WITHIN 10 GWH BAND WIDTHS
UNIT=3



86-67

FIG. 42

BRUCE-A CHANNEL ELONGATION RATES
AVERAGED WITHIN 10 GWH BAND WIDTHS
UNIT=4



86-67

APPENDICES

APPENDIX I

BULK ELONGATION RATES

UNIT	MEASUREMENT DATE	ELONGATION RATE (mm/GWH)*
1	1978 (selected data set)	0.117 ± 0.019
1	1980	0.094 ± 0.002
1	1983	0.103 ± 0.002
2	1979	0.111 ± 0.003
2	1981	0.111 ± 0.002
2	1982	0.110 ± 0.002
2	1985 (selected data set)	0.08 ± 0.04
2	1985	0.115 ± 0.002
3	1981	0.099 ± 0.002
3	1983	0.099 ± 0.001
4	1980	0.106 ± 0.003
4	1982	0.109 ± 0.002

* The interval represents the first Standard Deviation.

APPENDIX II

CHANNEL ELONGATION RATES

dE/dGWH vs Average GWH

The following are the slopes of the lines regressed through the 'CHANNEL' Elongation Rates as determined by two sets of elongation and fluence measurements.

UNIT	INTERVAL PERIOD	CHANGE IN RATE (mm./(GWH**2))*
1	1980 - 1983	0.00014 ± 0.00009
2	1979 - 1981	0.00009 ± 0.00002
2	1981 - 1982	0.00008 ± 0.00003
2	1982 - 1985 (full set)	0.00010 ± 0.00002
3	1981 - 1983	0.0002 ± 0.0001
4	1980 - 1982	0.00032 ± 0.00004

The following are the rates for the selected measurement sets. Due to small sample size of the measurement sets, the variance observed is large in some cases. This is especially true when the measurement period is short.

1	1978 - 1980	0.0002 ± 0.0003
1	1980 - 1980	0.0001 ± 0.00003
1	1980 - 1983	0.0001 ± 0.00003
2	1979 - 1981	0.0022 ± 0.0008
2	1981 - 1982	-0.003 ± 0.0008
2	1982 - 1985 (1st set)	0.0002 ± 0.0004
2	1985 (1st set) - 1985	0.002 ± 0.002

* The interval represents the first Standard Deviation

APPENDIX III

SELECTED CHANNEL ELONGATION RATE DATA FOR A SUBSET OF BRUCE UNIT 2 (dE/dGWH) (mm/GWH)

CHANNEL	1979-1981	1981-1982	1982-1985	1985-1985	1982-1985*
F 9	0.11	0.10	0.09	0.19	0.11
G 9	0.10	0.10	0.10	0.17	0.12
H 11	0.10	0.10	0.09	0.18	0.11
H 13	0.09	0.14	0.10	0.16	0.11
H 16	0.10	0.12	0.10	0.16	0.11
J 12	0.11	0.11	0.10	0.20	0.13
J 16	0.11	0.11	0.10	0.20	0.12
K 15	0.10	0.10	0.10	0.17	0.12
M 13	0.10	0.13	0.10	0.16	0.11
M 17	0.10	0.13	0.10	0.14	0.11
N 8	0.12	0.10	0.10	0.16	0.10
N 10	0.11	0.10	0.09	0.17	0.10
O 9	0.11	0.10	0.09	0.14	0.10
O 11	0.10	0.12	0.10	0.15	0.11
O 15	0.11	0.10	0.10	0.09	0.10
O 16	0.11	0.10	0.09	0.20	0.11
P 14	0.11	0.10	0.09	0.12	0.10
P 15	0.11	0.10	0.10	0.17	0.11
P 16	0.10	0.10	0.11	0.11	0.11
Q 17	0.11	0.10	0.09	0.17	0.10
R 16	0.11	0.11	0.10	0.18	0.11

* The closeness of the two sets of 1985 measurements (they were taken only 6 months apart) make them very susceptible to error when rate calculations are made due to small systematic measurement errors. The second set of 1985 measurements are in line with other measurements when compared with the 1982 set.